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Volume 7, Number 11, November 1966

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DATA

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RADIOLOGICAL HEALTH DATA AND REPORTS

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

NUCLEAR POWER PRODUCTION AND ESTIMATED KRYPTON-85 LEVELS

J. R. Coleman and R. Liberace[1]

Worldwide environmental levels of krypton–85 are projected to the year 2060, based on published estimates of population increase and prediction of world power needs. Factors considered include estimates of the growth of nuclear reactor power as a fraction of total power production based on population growth and per capita power consumption, the "mix" of the reactor economy (thermal, thermal converter, and fast breeder systems), and the decay rate of krypton–85 inventory. Krypton–85 buildup is discussed in relation to population dose and also to the possible effect of krypton–85 contamination on the uses of noble gases.

In 1962, the National Academy of Sciences, National Research Council (*1*), stated that if worldwide industrial collapse due to the exhaustion of fossil fuels and high-grade ores of metals within the next few centuries is to be forestalled, newer and larger sources of energy suitable to the requirements of large-scale industrial operations will be required.

With limited amounts of fossil fuels, with solar power an uncertain factor, and water power inadequate, nuclear energy alone appears of sufficient magnitude and adaptability to meet the world's future energy requirements. Thus, the orderly development of nuclear fuels as a primary source of worldwide energy must be considered a necessity. We must, however, remain continually aware of the environmental consequences of this rapidly expanding industry—the potential long-term buildup of radioactive waste materials in man's environment.

Because of the difficulty of their economical removal during fuel reprocessing noble gases are of special interest. The removal of such gases at the present time involves costly techniques which are reasonable only if very small volumes or flow rates are used. From the standpoint of long-term buildup, only krypton–85 with a half-life of approximately 10 years is of importance. Although the hazard associated with krypton–85 is not great, it was pointed out as early as 1959 that its long-term buildup in the environment would necessitate developing methods for removing it from power reactor fuel reprocessing off gases (*2,3*).

Already, minor nonhealth-related indications of the possible future problems of environmental krypton contamination have been observed. Ostrowski and Jelen (*4*) reported that the krypton–85 contamination present in commercial krypton as early as 1963 was a serious obstacle in the use of ionization detectors filled with this gas. Lasseart and Kellershohn (*5*) reported that krypton–85 contamination of xenon was mainly responsible for the background in a self-triggering spark chamber used in nuclear medicine.

[1] Mr. Coleman at the time of writing this article was chief of the Models and Predictions Staff Studies, Radiation Surveillance Center, and Mr. Liberace is a nuclear engineer associated with the Nuclear Facilities Environmental Analysis Section, Technical Operations Branch, both of the Division of Radiological Health, Public Health Service, Rockville, Maryland 20852.

Because of these implications and the possible radiation exposure to the population that might result from the long-term buildup of krypton–85, it is important that projections of the future environmental contamination be made. This paper presents an estimate of the magnitude of the levels of krypton–85 in air and the dose that would result from the long-term buildup in the earth's atmosphere over the next 100 years.

The method of approach was first to project world power needs to the year 2060 and then estimate the fraction of these needs that might be met by nuclear fuels. Once the total world nuclear power was estimated, a mixed reactor economy made up of thermal, thermal converter, and fast breeder systems was used to calculate the resulting krypton–85 production and its buildup in the earth's atmosphere as a function of time.

World nuclear energy usage

The major source of krypton–85 is expected to be the fission product gases released from plants processing spent nuclear fuel elements. In general, only a relatively small quantity would be released from actual reactor operations (*6,7*) and nuclear explosions (*8–10*).

For the purpose of this discussion it was assumed that the future production of krypton and the associated atmospheric contamination will closely follow the demands for nuclear electric power, nuclear ships, and other potential large users of nuclear energy. Although nuclear power growth projections for the United States have been made through the year 2000, and generalized projections to the year 2060 (*11*), any prediction of future krypton–85 levels in the earth's atmosphere must be based on estimates of the growth of the total nuclear industry throughout the world.

The method of estimating future nuclear power was based on an estimate of the total world input power requirements up to the year 2060 and a judgment as to the portion of this power that might conceivably be nuclear. Total world input energy was estimated by two methods. One was essentially the method used by Putnam (*12*) and the other utilized the data of Felix (*13*). To project world energy requirements by either of these methods requires a projection of both world population and annual per capita energy consumption.

The expression used for projecting world input energy requirements by the method of Putnam is shown in equation (1).

$$WE = \underbrace{N_o\,(1+\delta N_o)^{\tau}}_{\text{Population projection}}\ \underbrace{R_o(1+\delta R_o)^{\tau}\,\frac{1}{\epsilon(\tau)}}_{\text{Input energy projection}} \qquad (1)$$

where WE = net world annual input energy requirements, BTU,

N_o = 1947 world population,

δN_o = annual fractional increase in world population,

R_o = 1947 world average annual output energy requirement, BTU/person,

δR_o = annual fractional increase in world output energy requirement,

$\epsilon(\tau)$ = weighted average efficiency of input energy use,

and τ = time in years and using 1947 as a base.

Estimates of the world input energy were made on the basis of three population projections to 2050, one leading to a projected population of approximately 6 billion, another to a projected population of approximately 8 billion, and the third to a projected population of approximately 14 billion. The first two of these projected populations were selected to be consistent with the range of maximum plausible populations suggested by Putnam (*12*). The third value was selected to be in agreement with more recent population estimates made for the year 2000 by Cook (*14*). Cook estimated a world population of 5 to 7 billion by the year 2000, with a median value of approximately 6 billion. The third population estimate used in this investigation was based on an extrapolation of Cook's median projection to the year 2060.

Consistent with Putnam, the 1947 average per capita annual input energy requirement in equation (1) was taken as 3.98×10^7 BTU/capita·year (8.8×10^6 BTU/capita·year out-

put), and the annual fractional increase in world output energy requirements (δR_0) as 0.03. Although the rate of growth of world output energy demand is not constant and may be lower than 0.03, this value was selected by Putnam as a plausible contingency that must be considered. The weighted average efficiency [$\epsilon(\tau)$], defining the relationship between usable energy (electric power) and thermal energy, was taken to be 0.22 in 1947, with a linear increase to 0.36 in 1980, and a constant value of 0.36 from 1981 to 2060. As a result of increased industrialization, this changing efficiency was selected to reasonably represent the projected trend in weighted average efficiency for world energy use through the year 2060. The results of these calculations of world input energy demand are shown as curves 1, 2, and 3 in figure 1.

In calculating the world input energy requirements, utilizing the data of Felix, a changing growth rate for per capita input energy demand was used. That is, as the level of industrialization increases, the per capita consumption of energy increases but at a continuously slower rate. Thus, the calculations involve estimating the annual fractional increase in per capita consumption of energy as a function of the changing per capita consumption itself. The values used ranged from 0.036 in 1961 to approximately 0.010 in 2055. Annual per capita input energy requirements ranged from 4.06×10^7 BTU/capita·year in 1961 to 29.2×10^7 BTU/capita·year in 2060.

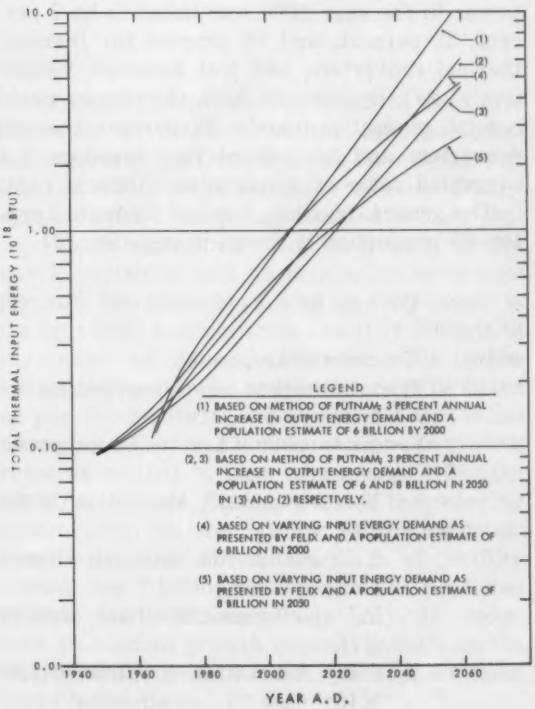

Figure 1. Estimated world input energy demand 1947–2060

Total world input energy requirements were then estimated by multiplying the estimated world per capita demand by the projected world population. Two population projections were used: the eight-billion estimate for the year 2050, and the median estimate based on Cook. The results of these calculations are shown as curves 4 and 5 in figure 1. In the remainder of this presentation, curve 2 in figure 1 will be used to represent a reasonable balance of the estimates of world energy, while the other curves will be used to represent the upper and lower range of values that might exist.

The fraction of the total world energy requirements supplied by nuclear power was estimated for the most part from consideration of the U.S. AEC Report to the President—1962 (*11*).[2] It was assumed that the world nuclear input energy might reasonably parallel the projections for the United States after the year 2000. Thus, projections were first made for the period from 2000 to 2060, assuming that the fraction of the world total input energy supplied by nuclear power would be approximately the same as that projected for the United States. Consistent with the report to the President, it was assumed that approximately 20 percent of the total input energy requirements (somewhat less than 50 percent of the electrical energy) might be satisfied by nuclear fuels in the year 2000. This fraction would increase to nearly 50 percent by the year 2060, at which time essentially all of the electrical energy would be supplied by nuclear power. The data of Felix would yield a somewhat lower estimate of the

[2] These predictions have already been exceeded by a factor of three for the past 3½ years.

proportion of total energy supplied by electricity. However, the estimates from the AEC's report to the President were selected as representing a reasonable projection of future demands.

For the period prior to the year 2000, it was assumed that the ratio of world nuclear energy to the United States nuclear energy would remain essentially constant. This ratio, based on the projected world nuclear energy demand (curve 2, figure 1) and the U.S. projection for the year 2000 (*11*), was found to be 2.82, a quite reasonable value in that the total world energy usage has been roughly three times that of the United States for approximately 100 years (*12*). The projected U.S. nuclear energy prior to the year 2000 was obtained from the report to the President.

The resultant curve for estimated world nuclear energy is shown in figure 2. As previously mentioned, curve 2 in figure 1 was used as the most reasonable balance between the upper and lower estimates. The upper and lower estimates are based on the extremes in the world energy projections from figure 1. It should be pointed out that the lower end of the curve is far more uncertain than it appears in the figure, due to the method of estimation.

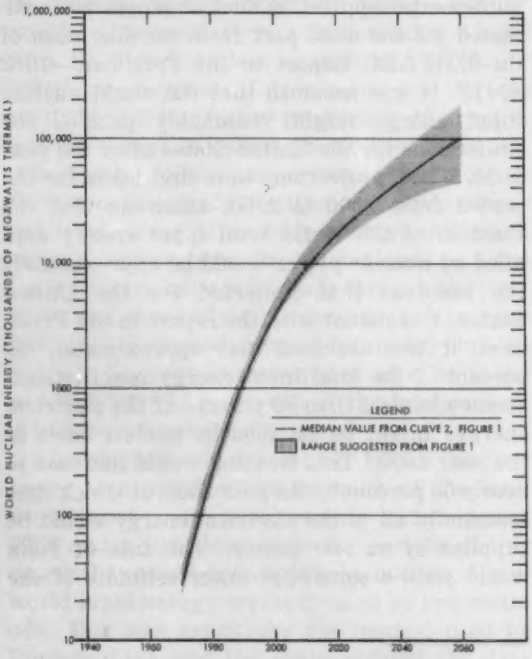

Figure 2. Estimated world nuclear energy (thermal), 1970–2060

Krypton–85 production, atmospheric concentration, and annual dose

For the purpose of calculating krypton–85 production, a mixed reactor system was assumed, since the fission yield of krypton–85 depends on the nuclear fuel used and the neutron energy. Three types of reactors were considered as comprising the mixed system:

1. Thermal (uranium–235)
2. Thermal converters (uranium–233, thorium–232)
3. Fast breeders (plutonium–239, uranium–238)

It was assumed that up until 1980, the total reactor complex would be made up of thermal systems utilizing uranium–235. In approximately 1980, thermal converters would come into use and shortly thereafter fast breeders would be introduced. The split in supplied power in the year 2000 was taken to be 7 percent, 33 percent, and 60 percent for thermal, thermal converters, and fast breeders, respectively (*15*). By the year 2020, the system would consist of approximately 20 percent thermal converters and 80 percent fast breeders, the suggested ratio of dynamic equilibrium (*15*).

The general equation used to estimate krypton–85 production is shown in equation (2).

$$C = 8.4 \times 10^5 \, P_i Y_i \, (1 - e^{-\lambda \tau}) \, e^{-\lambda t} \qquad (2)$$

where C = curies of krypton-85,
P_i = total nuclear power supplied by reactor system i, Mw
Y_i = fission yield of krypton-85 for reactor system i,
Y_i (uranium-235, thermal) = 0.00293 (*16*),
Y_i (uranium-233, thermal) = 0.0058 (*16*),
Y_i (plutonium-239, fast) = 0.00076 (*17*),
λ = decay constant for krypton-85 (1.84×10^{-4} days $^{-1}$),
τ = irradiation time (365 days),
and t = cooling time (150 days).

With the system defined, the annual krypton–85 production was calculated. The atmospheric concentration was then estimated by diluting the annual production into the total atmosphere and decaying the previous reservoir of krypton–85 by 1 year. The total atmosphere was taken to be 5.14×10^{21} grams (*18*). The results of these calculations are shown graphically in figure 3, and as before are presented as a median and a range. A second upper range is also presented, based on the consideration of 75 percent of the krypton–85 being released into the Northern Hemisphere and little interchange across the Equator. The 75 percent to 25 percent weighting is a rough estimate of the hemispheric population distribution beyond the year 2000. The concentrations are given in pCi/g of air, which corresponds roughly to 1,000 pCi/m^3 of air. Also shown in figure 3 are a number of measured values of krypton–85 in air (*10*) for comparison. In figure 4, the concentrations have been converted to dose by use of the relationships in the National Bureau of Standards Handbook 69 (*19*).

Discussion

Although the primary interest of this presentation is directed at the environmental buildup resulting from the long-term release of krypton–85 into the atmosphere, some discussion regarding the population and energy projections is warranted. Any projection of dynamic variables such as population or energy demand for periods as long as 100 years is fraught with uncertainties and it is difficult to reasonably assign probability or error to the values obtained. The projection must be based on past information; and inherent in this is the assumption that no dramatic changes in growth rates as related to past experiences will take place. In essence, Cook has stated that barring nuclear war, massive famine, worldwide catastrophe, or some miraculous form of fertility control, the 7-billion total population predicted by the year 2000 seems likely (*14*). However, such population growth depends greatly on the ability of the world economy to support these large populations.

Unless most of the inefficient farm cultures of underdeveloped nations transform to more efficient patterns of farming, populations of the magnitude projected would appear implausible (*12,14*). It is inevitable, therefore, that large populations must also be characterized by higher industrialization and relatively high demands for per capita energy consumption. The economy projected for the world in the year 2060 would be very nearly the level of industrialization of the United States today. The projections are based on past information and on estimations relating industrialization, energy use, and estimated population growth. In as far as the data from past experience can characterize future trends, the projections of world input energy demands are believed reasonable.

Throughout the presentation, several projections of world energy demands have been used in order to present a range of levels of krypton–85 that might be reasonably expected. On the basis of present knowledge, it would be difficult

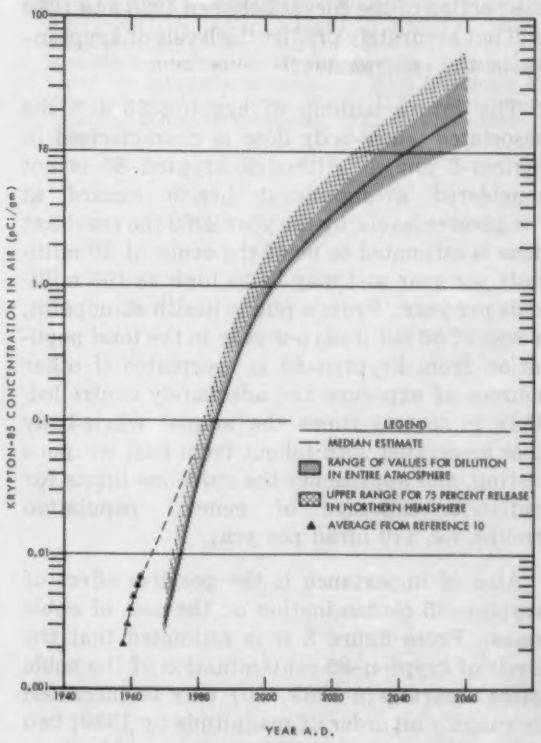

Figure 3. Estimated krypton–85 concentration in air 1970–2060

to visualize levels of krypton–85 differing from the projected median estimate after the year 2000 by more than an order of magnitude in the upward direction. Measures to reduce krypton–85 levels, including extraction at the source or replacement of fission power by fusion power, might make a greater change downward. At present the predicted values shown on the curves of figure 3 are not in agreement with the measured values of krypton–85 indicated by the single data points. This difference is due to inadequate knowledge of krypton–85 releases from fuel plants presently processing plutonium and other fissionable materials both in the United States and in other countries of the world. Since the quantity of fuel reprocessed by these government plants and by commercial plants cannot be estimated in the next few years, and because of the initial uncertainty in the delay between time when the fuel leaves the reactor core and the time when it is processed in a commercial fuel reprocessing facility, the portion of the curves between 1965 and 1980 will not accurately predict the levels of krypton–85 in the environment.

The future buildup of krypton–85 and the associated whole-body dose is characterized in figures 3 and 4. Although krypton–85 is not considered a significant health hazard at the present levels, by the year 2060 the resultant dose is estimated to be of the order of 50 millirads per year and may be as high as 100 millirads per year. From a public health standpoint, a dose of 50 millirads per year to the total population from krypton–85 is acceptable if other sources of exposure are adequately controlled. This is several times the annual whole-body dose associated with fallout from past weapons testing, and approaches the guideline limits for radiation exposure of general population groups, *i.e.* 170 mrad per year.

Also of importance is the possible effect of krypton–85 contamination on the uses of noble gases. From figure 3 it is estimated that the levels of krypton–85 contamination of the noble gases observed in 1963 (*10*) may be increased by roughly an order of magnitude by 1980; two orders of magnitude by 1990; and roughly three orders of magnitude by 2010. Table 1 presents the approximate specific activities for atmospheric krypton and total noble gases as calculated from the projection of figure 3.

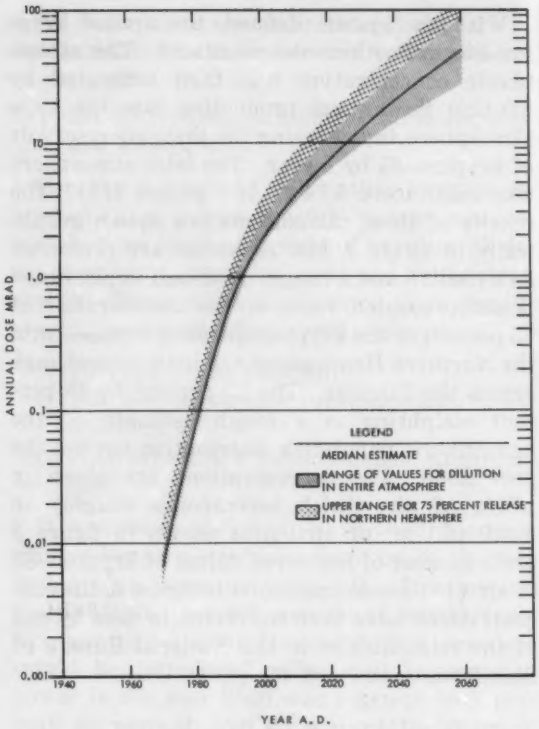

Figure 4. Estimated annual dose from krypton–85 1970–2060

In considering table 1, the question arises as to what limitations these levels might impose on the production and use of commercial noble gases, aside from possible future health considerations.

Our predictions indicate that krypton–85 remains as a potential future source of environmental contamination requiring evaluation by those concerned with the balancing of risks and benefits of nuclear energy.

Table 1. Activity due to krypton-85 in atmospheric noble gases

Gas	Estimated 1963 activity (dpm/g)	Projected future activity dpm/g noble gas				
		1980	2000	2020	2040	2060
Krypton-85	5.0×10^{3}	2.3×10^{4}	4.5×10^{5}	2.0×10^{6}	4.5×10^{6}	1.0×10^{7}
All other noble gases	2	9	180	800	1,800	4,000

Acknowledgment

The authors wish to express their thanks to Mr. Richard Grundy[3] for the computer programming and systems analysis associated with this investigation.

[3] Chief, Data Collation and Analysis Section, Radiation Surveillance Center, Division of Radiological Health, Public Health Service, Washington, D.C. 20201.

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FILM BADGE SERVICE PERFORMANCE[1]

D. E. Barber[2]

Approximately 2,000 film badges were irradiated with various types and energies of radiation to provide measures of film badge service accuracy upon which provisional performance control limits could be based. Exposures ranged from 2 milliroentgens to 497 roentgens. Film badge services 1) helped design the test procedures, 2) submitted badges for exposure, 3) reported exposure interpretations, and 4) assisted in determining provisional performance control limits. A measure of accuracy called an *error factor* was determined for each service for each type and energy of radiation in the test. These error factors are tabulated to show the accuracy of the film badge services tested. Frequency distributions of the error factors served as the basis for selection of provisional control limits to be used to define acceptable performance.

Reported here are the results of the most extensive test ever undertaken of the performance of film badge services. The test was conducted in 1965 by the National Sanitation Foundation (the Foundation) and included examination of commercial and federal film badge services. The work was done in response to a general concern about the accuracy with which film badge services report radiation exposures.

Procedures

Twenty-five different organizations (one company submitted two sets of film) each submitted 80 badges to the Foundation for irradiation with the various types, energies, and doses of radiation shown in table 1. Twelve of the 25 organizations were commercial film badge companies. After irradiations were completed by the Foundation, badges were returned to their suppliers for exposure evaluation. All services were informed of the test procedures to be used prior to the test. However, services had no prior knowledge of which badges were exposed to what type, energy, or dose of radiation.

Irradiation techniques used in the test have been described in detail in other reports (*1*,*2*).

Results

Log-log coordinate graphs of reported (y) versus delivered (x) irradiations were prepared for each film badge service and each type and energy of radiation used in the test. Figure 1 is an example of such a graph.

An "error factor" was then determined as follows: first, the reported irradiation geometrically farthest from the line, $y=x$, was noted and omitted from further consideration. (See discussion). The point that lay next farthest from the line, $y=x$, was then designated the "error factor point."

The "error factor," Y_e/X_e, was determined from the coordinates of the error factor point. This factor was used as the measure of accuracy of a service for each type and energy of radiation used in the test. Note that the error factor may be greater than 1.0, or less than 1.0 (as in figure 1). The upper error band has the equation $X=(X_e/Y_e)\ Y$, and the lower error band the equation $X=(Y_e/X_e)\ Y$. Although the error bands are geometrically equidistant from the perfect performance line, they do not

[1] The work upon which this article is based was supported by the U.S. Public Health Service Contract No. PH 86–63–198 with the National Sanitation Foundation, School of Public Health, Ann Arbor, Michigan.

[2] At the time of this study, Dr. Barber was assistant professor, Department of Environmental Health, University of Michigan; he is now associate professor in the Environmental Health Department, School of Public Health, Mayo Hospital, University of Minnesota, Minneapolis.

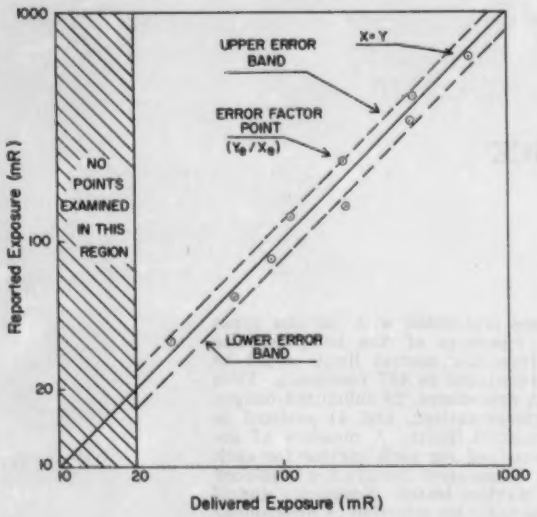

Figure 1. Example data showing a method of selecting the reported exposure used to determine the error factor

represent the same percentage error. To illustrate: an error factor of either 0.5 or 2.0 means that all but one of the points fall within minus 50 percent and plus 100 percent of the delivered exposures.

Error factors were computed separately for the gamma and beta components of mixed beta and gamma irradiations.

The error factors for the different organizations for each of the various types and energies of radiation in the test are shown in table 2. These data represent a measure of the present performance level of film badge services, and serve as the basis for the provisional performance criteria given in table 3. The control limits in table 3 were determined as follows:

1. The pooled frequency distribution (figure 2) of all the error factors in table 2 was examined. The error factors 0.20 and 1.80 were selected arbitrarily from figure 2 to be reasonable values for control limits for the film badge service industry as a whole. These error factors were chosen to encompass approximately 80 percent of all the error factors in figure 2.

2. The frequency distributions of the error factors for each type and energy of radiation in table 2 were then examined individually and qualitatively compared with the pooled distribution. If an individual distribution was broader than the pooled distribution, the control limits, chosen from the pooled distribution,

Table 1. Film badge irradiations per film badge service [a]

Group	Radiation	Added filter (mm)	kVp or source	1st HVL [b] 2nd HVL (mm)	Effective energy [c] (keV)	Irradiation range	Total number of film badges	Number of film badges receiving >20 mrem [d]
1	X-ray	1 Al	68	1.05 Al 2.00	23	6–288 mR	9	6
2	X-ray	1 Cu+1 Al	200	1.35 Cu 2.35	90	3–186 mR	9	6
3	X-ray	1 Sn+1 Cu+Th II [e]	270	4.10 Cu 5.60	175	9–287 mR	9	8
4	X-ray	1 Sn+1 Cu+Th II [e]	270	4.10 Cu 5.60	175	2–497 R	4	4
5	Gamma	Capsule only [f]	^{137}Cs	—	662	11–305 mR	9	8
6	Beta	Capsule only [g]	^{90}Sr-Y	—	—	23–276 mrad [h]	9	9
7	Beta+gamma	Capsule only [g] Capsule only [f]	^{90}Sr-Y + ^{137}Cs	— 662	— 662	28–136 mR	9	9
8	X-ray+gamma	1 Al Capsule only [f]	68 ^{137}Cs	1.05 Al —	23 662	17–390 mR	9	8
9	Fast neutrons	Capsule only [i]	Pu-Be	—	—	17–228 mrem	9	8
10	None	Two controls for neutron film badges+two controls for all others				None	4	0

[a] Relative humidity during irradiations varied from 14 percent to 43 percent. Temperature varied from 23° to 27° C.
[b] Half-value-layer.
[c] Based on first HVL.
[d] The decision to eliminate from the test all doses less than 20 mrem was made after all irradiations had been completed.
[e] Th II = 0.4 mm Sn+0.25 mm Cu+1.0 mm Al.
[f] The ^{137}Cs source is encapsulated in 30 mils 303 S.S.+30 mils 321 S.S.
[g] The ^{90}Sr-Y source has a 21 mg/cm^2 aluminum end window.
[h] The neutron source is encapsulated in 100 mils of tantalum+30 mils of 304 S.S.
[i] Measured in air.

Table 2. Error factors (encompassing all but one of the data points) for irradiations greater than 20 mrem

Service code	Radiation										
	23 keV X	90 keV X	175 keV X low exposure	175 keV X high exposure	Beta	Gamma	β of $(\beta+\gamma)$	γ of $(\beta+\gamma)$	X+γ	Fast neutrons	Total asterisks
1	0.80	*2.66	0.84	*0.50	*3.64	*0.22	*0.01	*0.04	*0.49	—	7
2	*2.29	0.87	0.76	0.85	1.34	*0.69	1.58	*1.43	1.79	*0.04	4
3	1.14	1.02	0.90	0.66	1.43	0.81	1.30	0.80	0.85	0.76	0
4	*2.18	0.71	*0.12	*0.44	*1.52	*0.59	1.56	*0.65	1.36	2.00	6
5	0.79	*0.41	0.76	*>0.61	*1.74	1.31	*0.01	*0.43	*0.44	*0.02	7
7	*0.22	0.83	*0.53	0.83	*2.50	0.82	*3.35	0.89	*0.52	1.26	5
8	0.87	0.62	1.59	*1.68	1.30	*0.59	1.37	0.89	0.59	0.67	2
9	*3.00	0.61	*0.46	*0.36	1.41	0.77	*0.02	*0.64	*0.44	*6.70	7
9b	*0.54	0.61	*0.42	*0.02	*0.06	0.85	*0.01	*0.65	—	*4.42	7
11	1.13	1.03	0.83	1.05	1.09	0.82	0.85	0.72	1.10	1.59	0
12	0.84	*0.46	*0.50	0.63	1.41	0.80	1.77	0.82	0.83	0.80	2
13	0.75	0.64	*0.53	0.67	1.28	0.76	*0.01	*0.66	0.73	0.72	3
14	0.79	1.61	1.30	*0.52	1.29	0.88	1.46	1.12	*0.49	1.30	2
15	1.05	*0.57	0.77	1.09	*0.10	0.78	0.87	0.89	0.46	*0.23	3
16	1.50	0.88	0.68	1.15	0.93	1.22	0.61	1.29	0.68	*3.14	1
16b	1.37	0.92	0.75	0.91	1.22	1.19	0.81	*1.45	—	—	1
17	0.75	0.71	*0.45	0.67	1.08	0.78	1.30	0.73	—	1.31	1
18	*0.31	*0.24	*0.23	*0.07	*0.13	*0.33	—	—	*0.22	—	7
19	0.80	0.60	*0.54	0.70	*2.22	0.82	*2.45	*0.29	0.63	1.92	4
21	*2.04	*2.82	*2.16	0.73	*2.01	*2.55	0.64	1.19	*2.90	*0.01	7
22	*0.42	1.59	0.64	*>26.3	*0.43	*0.33	*0.02	*1.78	*0.24	*0.01	8
23	1.09	*3.94	1.25	*>1.20	*0.04	1.29	1.90	1.10	*0.52	*0.43	5
23b	*0.11	0.79	1.08	1.40	*0.05	1.27	0.96	1.10	*0.48	*0.34	4
24	1.27	0.68	1.58	*2.10	0.86	0.85	0.81	1.37	0.58	0.68	1
25	*2.09	1.67	*0.42	*>1.82	0.69	*0.01	*0.02	*1.85	*2.27	*2.57	8
26	0.90	*0.48	*0.54	0.80	0.87	0.87	1.22	0.86	—	0.59	2
Total asterisks	10	8	12	12	12	8	9	11	11	11	104

Notes:
Asterisks mean the error factor falls outside proposed control limits in table 3.
Dashes mean the service either did not provide reports for the indicated radiation or was not tested for the indicated radiation.
A "b" after the service code identifies film badges obtained through State health departments. Film badge services were not advised of the use of these badges.

were expanded and adopted for the radiation appropriate to the individual distribution. Similarly, if the individual distribution appeared narrower than the pooled distribution, the control limits applicable to the particular radiation in question were narrowed.

After the control limits were adjusted, it was observed that greater than one-half of the services fell within the control limits in table 3 for the individual types and energies of radiation in table 2. About two-thirds of the services demonstrated error factors which fell within the control limits for five or more radiation categories.

Discussion

This work involved the examination of film badge service performance for a number of radiation types, radiation energies, and irradiation ranges selected so that the majority of exposure conditions encountered in personal dosimetry were included. The data show that there is a rather broad gap between the better group and poorer group of services. The control limits would have to be expanded almost to the range of the error factors in table 2 to change appreciably the number of services in table 2 which demonstrated error factors within all the control limits in table 3.

It is not surprising that only two services demonstrated error factors which lay within all the control limits, because:

1. The individual frequency distribution for each type or energy of radiation in table 2 involved at most 26 error factors. This is a small number of observations for plotting frequency distributions. Where the observations were widely distributed, it was not clear what control limits should be chosen for the particular radiation in question.

2. Services demonstrated error factors over a broad range from one type of radiation to another.

An arbitrary degree of freedom was introduced into the test by ignoring the reported irradiation farthest from the line $y=x$, figure 1. This was done to reduce the likelihood of a service failing a subsequent test on a purely statistical basis. If the point farthest from the line $y=x$ had been used as the basis for control limits, all reported irradiations in a category would be involved in tests against the control

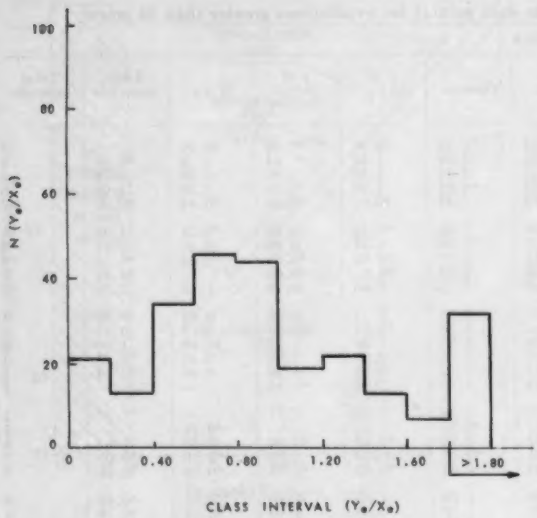

Figure 2. Pooled distribution of Y_e/X_e

limits, and chance would play a stronger role in the failure of services to meet the control limits in subsequent tests. On the other hand, had the point closest to the line y=x been used, only one out of nine reported irradiations in a category (1 out of 4 for the high exposure x-ray group) would be involved in tests against the control limits, and the likelihood of success in future tests for purely statistical reasons would be high. More tests will have to be made before the probability of successes in repeated tests can be determined statistically.

A number of methods of analyzing the data were examined, but it developed that the simple analysis described proved sufficient for the present. The analysis does not require replicate exposures; it is simple and it permits a wide range of exposures to be examined with a small number of badges. Replicate exposures would provide services with clues to the correct answers but much larger numbers of badges would be required. Further, with no replicates it is difficult for film badge services to anticipate the results.

The fact that the control limits adopted from this test are comparable with the interim control limits proposed by the Atomic Energy Commission in 1963 (*3*) should not be construed to mean that the control limits proposed by either the Foundation or the AEC represent satisfactory performance in personal dosimetry. The control limits reflect only the present level of performance of film badge services.

This and subsequent tests should enable film badge services to recognize and correct sources of error. As the services improve, the control limits may be narrowed. However, the extent to which they may be narrowed can be determined accurately only with data from additional testing.

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(*2*) BARBER, D. E. Standards of performance for film badge services, PHS Publication No. 999–RH–20. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (In press).

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Table 3. Film badge performance control limits

Radiation category [b]	Irradiation range for test	Error factor control limits		Percentage error band [c]	
		Upper	Lower	Upper	Lower
X rays, 15–30 keV	20–600 mR	1.50	0.67	50	33
X rays, 0.03–0.2 MeV	20–600 mR	1.70	0.59	70	41
X rays, 0.15–0.2 MeV	1–500 R	1.60	0.63	60	37
Gamma, 0.2–3 MeV	20–600 mR	1.40	0.71	40	29
Beta	40–600 mrad	1.50	0.67	50	33
Beta of $\beta+\gamma$	40–600 mrad	2.00	0.50	100	50
Gamma [e] of $\beta+\gamma$	20–600 mR	1.40	0.71	40	29
X [d] + gamma [e]	20–600 mR	1.90	0.53	90	47
Fast neutron	50–600 mrem	2.00	0.50	100	50

[a] Energy ranges and types of radiation involved in the test are known to the film badge services but the type and energy of radiation delivered to a specific badge is unknown.
[b] Sources are described in detail in table 1.
[c] Gamma rays of 0.2 to 3 MeV energy.
[d] X rays of 15–30 keV.
[e] $1-|Y_e/X_e|\,100$.

Section I. Milk and Food

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Efforts are being made by both Federal and State agencies to monitor the intake of various radionuclides in the total diet on a continuing basis. Although the total diet is the most direct measure of intake of radionuclides, indicator foods may be used to estimate dietary intake where specific dietary data are not available. As fresh milk is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides from nuclear test debris which appear in the diet, it is the single food item most often used as an indicator of the population's intake of radionuclides. Moreover, it is the major source of dietary intake of short-lived radionuclides. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk. More direct estimates of dietary intake of radionuclides than those furnished by indicator foods can be obtained by analyses of the total diet or representative principal food items or groups combined with appropriate consumption data.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1-3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; however, they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected National, International, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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NATIONAL AND INTERNATIONAL MILK SURVEILLANCE

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various National and International organizations routinely monitor radionuclide levels in milk. In addition to the programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	July–December 1965	June 1966

1. Pasteurized Milk Network July 1966

Division of Radiological Health and Division of Environmental Engineering and Food Protection, PHS

The Public Health Service's Pasteurized Milk Network (PMN) was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 sampling stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the December 1965 issue of *Radiological Health Data* (*1*).

Figure 1. Pasteurized Milk Network sampling stations

Table 1. Average concentrations of radionuclides in pasteurized milk for the second quarter and July 1966 [a]

Sampling location		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)		Iodine-131 (pCi/liter)		Barium-140 (pCi/liter)	
		Second quarter [b] 1966	July 1966	Second quarter 1966	July 1966	Second quarter 1966	July 1966	Second quarter 1966	July 1966	Second quarter 1966	July 1966
Ala:	Montgomery		<5	12	12	25	25	10	0	0	0
Alaska:	Palmer		<5	15	14	40	30	0	20	0	0
Ariz:	Phoenix		<5	3	3	10	10	0	0	0	0
Ark:	Little Rock		10	32	24	40	30	40	0	10	0
Calif:	Sacramento		<5	9	5	15	15	0	20	0	0
	San Francisco		<5	9	3	20	15	0	0	0	0
C.Z:	Cristobal		<5	4	4	20	15	0	0	0	0
Colo:	Denver		<5	11	8	25	20	0	0	0	0
Conn:	Hartford		<5	13	11	40	35	0	0	0	0
Del:	Wilmington		<5	17	13	40	30	0	0	0	0
D.C:	Washington		<5	13	12	30	25	0	0	0	0
Fla:	Tampa		<5	10	10	125	125	0	0	0	0
Ga:	Atlanta		5	20	19	40	40	10	0	0	0
Hawaii:	Honolulu		<5	6	5	30	20	0	0	0	0
Idaho:	Idaho Falls		<5	14	6	40	25	0	0	0	0
Ill:	Chicago		<5	13	9	35	25	0	0	0	0
Ind:	Indianapolis		5	13	11	30	20	20	0	0	0
Iowa:	Des Moines		5	16	15	30	20	10	0	0	0
Kans:	Wichita		<5	14	12	20	10	20	0	0	0
Ky:	Louisville		10	19	15	20	15	0	0	0	0
La:	New Orleans		10	32	37	45	65	0	0	0	0
Maine:	Portland		<5	16	18	70	60	0	0	0	0
Md:	Baltimore		<5	15	13	30	25	0	0	0	0
Mass:	Boston		<5	17	15	60	60	0	0	0	0
Mich:	Detroit		<5	12	9	30	25	0	0	0	0
	Grand Rapids		<5	16	14	45	35	0	0	0	0
Minn:	Minneapolis		5	23	21	40	35	0	0	0	0
Miss:	Jackson		10	26	22	30	30	10	0	0	0
Mo:	Kansas City		10	17	13	25	15	30	0	0	0
	St. Louis		15	19	17	30	25	30	0	0	0
Mont:	Helena		<5	14	12	55	30	0	0	0	0
Nebr:	Omaha		10	15	13	30	20	10	0	0	0
Nev:	Las Vegas		<5	6	4	25	10	0	0	0	0
N.H:	Manchester		<5	17	23	80	95	0	0	0	0
N.J:	Trenton		<5	13	12	30	25	0	0	0	0
N. Mex:	Albuquerque		<5	6	5	20	10	0	0	0	0
N.Y:	Buffalo		<5	12	11	40	25	0	0	0	0
	New York		<5	15	15	40	35	0	0	0	0
	Syracuse		<5	13	11	40	25	0	0	0	0
N.C:	Charlotte		5	20	21	30	30	20	0	0	0
N. Dak:	Minot		5	34	21	40	25	0	0	0	0
Ohio:	Cincinnati		<5	15	12	25	15	0	0	0	0
	Cleveland		<5	14	12	35	25	0	0	0	0
Okla:	Oklahoma City		<5	14	11	20	15	20	0	0	0
Ore:	Portland		<5	14	12	40	30	0	0	0	0
Pa:	Philadelphia		<5	14	13	35	25	0	0	0	0
	Pittsburgh		<5	19	19	45	25	0	0	0	0
P.R:	San Juan		<5	8	7	25	20	0	0	0	0
R.I:	Providence		<5	15	17	45	45	0	0	0	0
S.C:	Charleston		<5	21	21	50	55	20	0	0	0
S. Dak:	Rapid City		10	21	16	45	30	0	0	0	0
Tenn:	Chattanooga		5	21	20	30	30	0	0	0	0
	Memphis		5	19	16	20	15	20	0	0	0
Tex:	Austin		<5	6	5	15	10	0	0	0	0
	Dallas		<5	16	10	25	15	20	0	0	0
Utah:	Salt Lake City		<5	12	10	35	25	0	0	0	0
Vt:	Burlington		<5	14	15	50	40	0	0	0	0
Va:	Norfolk		<5	16	16	30	25	0	0	0	0
Wash:	Seattle		<5	18	23	55	65	0	0	0	0
	Spokane		<5	18	16	40	40	0	10	0	0
W. Va:	Charleston		<5	17	15	20	20	0	0	0	0
Wis:	Milwaukee		<5	10	9	40	25	0	0	0	0
Wyo:	Laramie		<5	12	11	30	30	0	0	0	0
Network average			<5	15.2	13.4	36	30	5	1	0	0

[a] Calcium analyses were discontinued as of March 1966.
[b] Quarterly averages are not reported since monthly averages for April were not calculated as only 10 percent of the samples were analyzed for strontium-89.

Table 2. Frequency distribution, strontium-90 concentrations in milk at Pasteurized Milk Network stations, July 1965 and February–July 1966

Strontium-90 (pCi/liter)	Number of stations						
	1965	1966					
	July	Feb	Mar	Apr	May	June	July
Under 10	8	9	9	8	10	9	14
10–19	34	46	44	50	38	41	39
20–29	18	7	7	3	12	10	9
30–39	3	1	3	2	3	3	1
40–49	0	0	0	0	0	0	0

Table 3. Frequency distribution, cesium-137 concentrations in milk at Pasteurized Milk Network stations, July 1965 and February–July 1966

Cesium-137 (pCi/liter)	Number of stations						
	1965	1966					
	July	Feb	Mar	Apr	May	June	July
Under 50	34	56	56	55	51	56	56
50–99	25	6	6	7	11	6	6
100–149	3	1	1	1	1	1	1
150–199	1	0	0	0	0	0	0
200–249	0	0	0	0	0	0	0

The results for July and the second quarter of 1966 are presented in table 1. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. However, because of the Chinese nuclear detonation, the sampling frequency was increased to twice a week from mid-May until the end of June. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable value; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 2 and 3 for July 1965 and February through July 1966. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

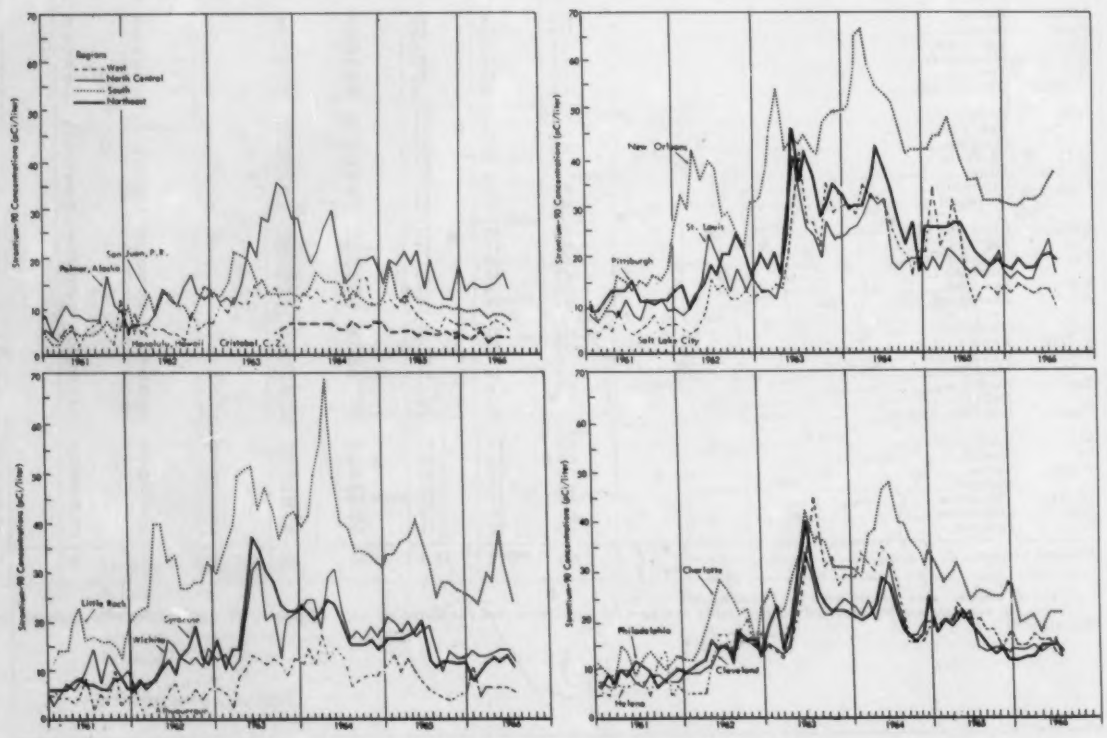

Figure 2. Strontium–90 concentrations in pasteurized milk 1961–July 1966

2. Canadian Milk Network July 1966[1]

Radiation Protection Division
Department of National Health and Welfare
Ottawa, Canada

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1965 issue of *Radiological Health Data* (*2*).

The July 1966 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 4. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

[1] Prepared from July 1966 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 4. Stable elements and radionuclides in Canadian whole milk, July 1966

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.11	1.5	16	37
Edmonton	1.09	1.5	15	61
Ft. William	1.03	1.6	17	53
Fredericton	1.07	1.6	23	68
Halifax	1.11	1.6	20	59
Montreal	1.07	1.5	15	43
Ottawa	1.11	1.5	12	33
Quebec	1.07	1.6	21	56
Regina	1.09	1.5	15	32
St. John's, Nfld.	1.09	1.6	44	167
Saskatoon	1.09	1.6	12	31
Sault Ste. Marie	1.09	1.6	24	59
Toronto	1.08	1.6	7	28
Vancouver	1.15	1.6	25	102
Windsor	1.12	1.6	15	19
Winnipeg	1.04	1.6	14	53
Average	1.09	1.6	18.4	56

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program July 1966

Pan American Health Organization and U.S. Public Health Service

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between both agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Information on the sampling and analytical procedures employed was presented in the December 1965 issue of *Radiological Health Data* (*3*).

Table 5 presents stable calcium and potassium, strontium–89, strontium–90, iodine–131, cesium–137, and barium–140 monthly average concentrations for July 1966.

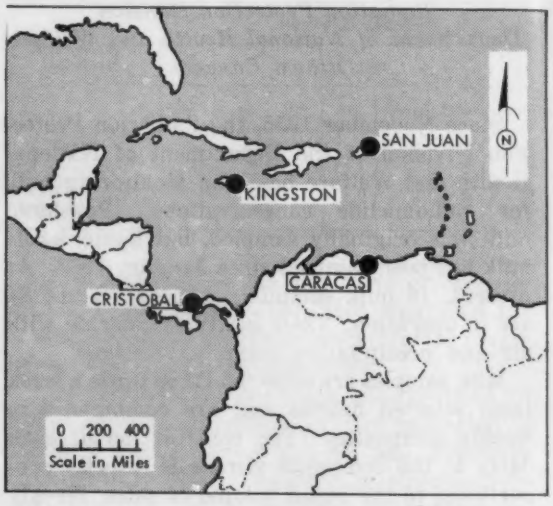

Figure 4. Pan American Milk Sampling Program locations

Table 5. Stable element and radionuclide concentrations in PAHO milk, July 1966

Sampling location	Calcium (g/liter)	Potassium (g/liter)	Strontium-89 (pCi/liter)	Strontium-90 (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)	Barium-140 (pCi/liter)
Ecuador:							
Guayaquil—							
Zone 1 [a] (9) [b]		1.58	<5	1	18	5	<10
Zone 2 (3)		1.49	<5	1	40	<5	<10
Zone 3 (2)		1.54	<5	2	<10	8	<10
Jamaica:							
Kingston	1.15	1.50	30	9	10	100	10
Mandeville	NS						
Montego Bay	NS						
Venesuela:							
Caracas (July)	1.10	1.55	<5	6	<10	5	10
June 1966[c]	1.08	1.45	<5	4	<10	10	<10
Canal Zone:							
Cristobal	—	—	<5	4	0	15	0
Puerto Rico:							
San Juan	—	—	<5	7	0	20	0

[a] Averages are calculated by the same method as that used for the Pasteurized Milk Sampling Network.
[b] Numbers in parentheses indicate number of samples.
[c] Data received too late for inclusion in October issue.
NS, no sample reported.

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(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1965. Radiol Health Data 6:687 (December 1965).

STATE MILK SURVEILLANCE ACTIVITIES

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs supported by functional radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of dietary intake of radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

State milk network	Period reported	Last presented
California	January–March 1966	September 1966
Colorado	May 1965–June 1966	October 1966
Florida	April–June 1966	October 1966
Oklahoma	April–June 1966	October 1966
Oregon	January–March 1966	September 1966
Texas	April–June 1966	October 1966
Washington	January–March 1966	September 1966

1. Connecticut Milk Network April–June 1966

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 1). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma emitters are determined by gamma-scintillation spectrometry.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in central Connecticut pasteurized milk are presented in table 1. Results obtained since 1962 are presented graphically in figure 2.

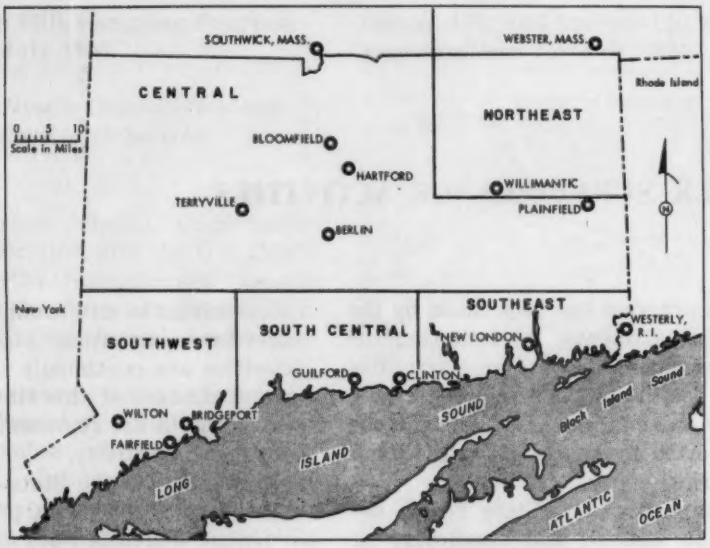

Figure 1. Connecticut pasteurized milk sampling areas

Table 1. Radionuclide concentrations in central Connecticut milk, April–June 1966

Month 1966	Concentration, pCi/liter			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
April	<1	10	<10	30
May	<1	10	<10	30
June	<1	14	<10	30

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
Annual summary 1963	September 1964
Annual summary 1964	May 1965
Annual summary 1965	May 1966
January–March 1966	August 1966

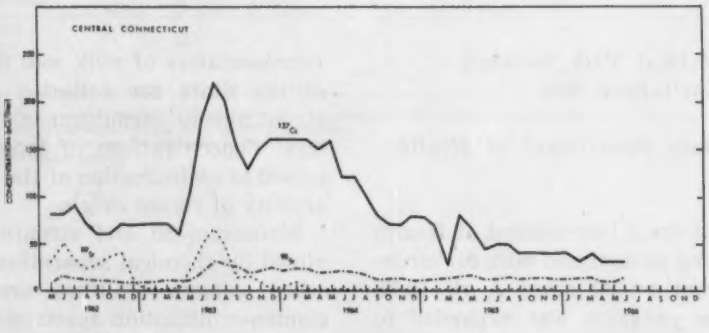

Figure 2. Radionuclide concentrations in central Connecticut pasteurized milk 1962–June 1966

2. Indiana Milk Network April–June 1966

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds: northeast, northwest, central, southeast, and southwest (figure 3). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium–89 and strontium–90. Iodine–131, cesium–137, and barium–140 are analyzed weekly for at least two of the milksheds. When iodine–131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for northeast, southeast, and southwest milksheds.

Strontium–89 and strontium–90 concentrations in milk samples are determined by ion

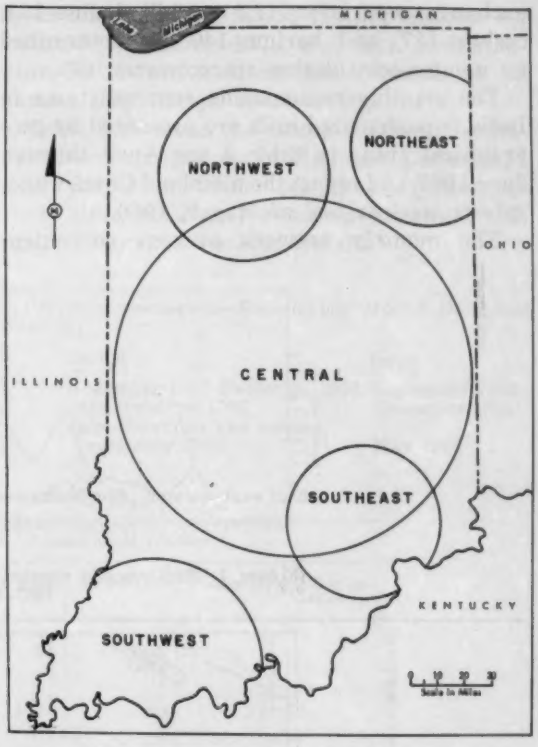

Figure 3. Indiana pasteurized milk sampling areas

Table 2. Radionuclides in Indiana milk, April–June 1966

Element and month	Sampling locations					
	Northeast	Southeast	Central	Southwest	Northwest	Average
Calcium (g/liter)						
April	1.20	1.20	1.17	1.20	1.17	1.19
May	1.16	1.14	1.14	1.14	1.14	1.14
June	1.20	1.18	1.20	1.18	1.20	1.19
Potassium-40 (pCi/liter)						
April	1,360	1,360	1,310	1,310	1,320	1,330
May	1,390	1,450	1,350	1,320	1,370	1,380
June	1,300	1,400	1,330	1,350	1,330	1,340
Strontium-89 (pCi/liter)						
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	5	10	25	5	10	10
Strontium-90 (pCi/liter)						
April	9	13	11	12	10	11
May	11	13	11	16	13	13
June	20	18	18	24	18	20
Iodine-131 (pCi/liter)						
April	0	0	0	0	0	0
May	40	35	70	20	100	50
June	10	10	40	10	40	20
Cesium-137 (pCi/liter)						
April	25	30	25	25	30	25
May	35	35	30	30	40	35
June	25	35	20	25	35	30
Barium-140 (pCi/liter)						
April	0	0	0	0	0	0
May	0	10	10	0	20	10
June	0	0	10	0	10	0

exchange separation (*1,2*), while iodine–131, cesium–137, and barium–140 are determined by gamma-scintillation spectrometry (*3*).

The monthly radionuclide concentrations in Indiana pasteurized milk are presented by geographical areas in table 2 for April through June 1966, and reflect the mainland China atmospheric nuclear test of May 9, 1966.

The monthly network average concentrations of strontium–89, strontium–90, and cesium–137 are presented graphically in figure 4.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
September–December 1964 and summaries 1961–1964	May 1965
Annual summary 1965	May 1966
January–March 1966	August 1966

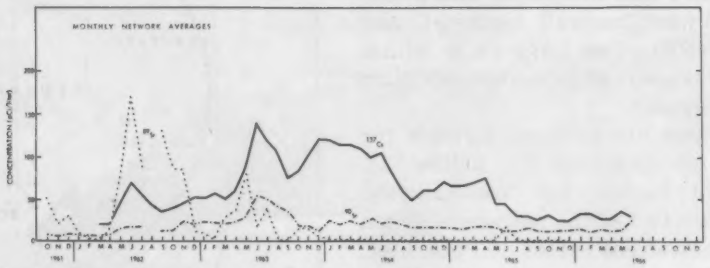

Figure 4. Radionuclide concentrations in Indiana pasteurized milk 1961–June 1966

Figure 5. Michigan milk network sampling stations

3. Michigan Milk Network January–June 1966

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analysis in November 1964. Under this program, weekly pasteurized milk samples are collected in the seven major milk-producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 5). Milkshed samples are composites from dairies in proportion to sales volumes.

Strontium–90 concentrations are determined by an ion exchange method (*4*). Potassium–40, iodine–131, cesium–137, and barium-lanthanum–140 concentrations are determined by gamma-scintillation spectrometry (*4*).

Table 3 presents the monthly average radionuclide concentrations in Michigan pasteurized milk. Strontium–90 and cesium–137 concentrations since 1962 are presented graphically in figure 6, to show general trends.

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
November 1962–December 1964	September 1965
January–June 1965	November 1965
July–December and annual summary 1965	May 1966

Table 3. Radionuclides in Michigan pasteurized milk, January–June 1966

Location	Month 1966	Concentrations, pCi/liter				
		Potassium-40	Strontium-90	Iodine-131	Cesium-137	Barium-lanthanum-140
Charlevoix	January	1,370	15	<14	34	0
	February	1,380	13	<14	41	0
	March	1,370	11	<14	40	0
	April	1,380	12	<14	39	0
	May	1,390	NA	<14	36	0
	June	1,370	16	<16	33	0
Detroit	January	1,320	NA	<14	24	0
	February	1,350	8	<14	27	0
	March	1,360	7	<14	28	0
	April	1,340	6	<14	60	0
	May	1,360	NA	<14	29	0
	June	1,320	10	<14	23	0
Grand Rapids	January	1,350	NA	<14	34	0
	February	1,350	10	<14	38	0
	March	1,370	10	<14	40	0
	April	1,400	9	<14	44	0
	May	1,360	NA	<14	46	0
	June	1,340	13	<14	33	1
Lansing	January	1,350	8	<14	28	0
	February	1,330	8	<14	30	0
	March	1,380	7	<14	34	0
	April	1,320	6	<14	35	0
	May	1,320	NA	<14	36	0
	June	1,300	9	<14	24	0
Marquette	January	1,380	NA	<14	48	0
	February	1,370	18	<14	63	0
	March	1,370	19	<14	60	0
	April	1,380	NA	<14	61	0
	May	1,340	NA	<14	68	0
	June	1,340	NA	<14	58	1
Monroe	January	1,360	5	<14	19	0
	February	1,320	6	<14	22	0
	March	1,350	5	<14	23	0
	April	1,360	6	<14	29	0
	May	1,370	NA	<14	25	0
	June	1,370	10	<14	24	0
Saginaw	January	1,360	8	<14	23	0
	February	1,370	7	<14	29	0
	March	1,390	7	<14	31	0
	April	1,350	6	<14	34	0
	May	1,340	NA	<14	33	0
	June	1,310	11	<14	27	0
Average	January	1,360	9	<14	30	0
	February	1,350	10	<14	36	0
	March	1,370	9	<14	37	0
	April	1,360	8	<14	43	0
	May	1,350	NA	<14	39	0
	June	1,340	12	<14	32	0

NA, no analysis.

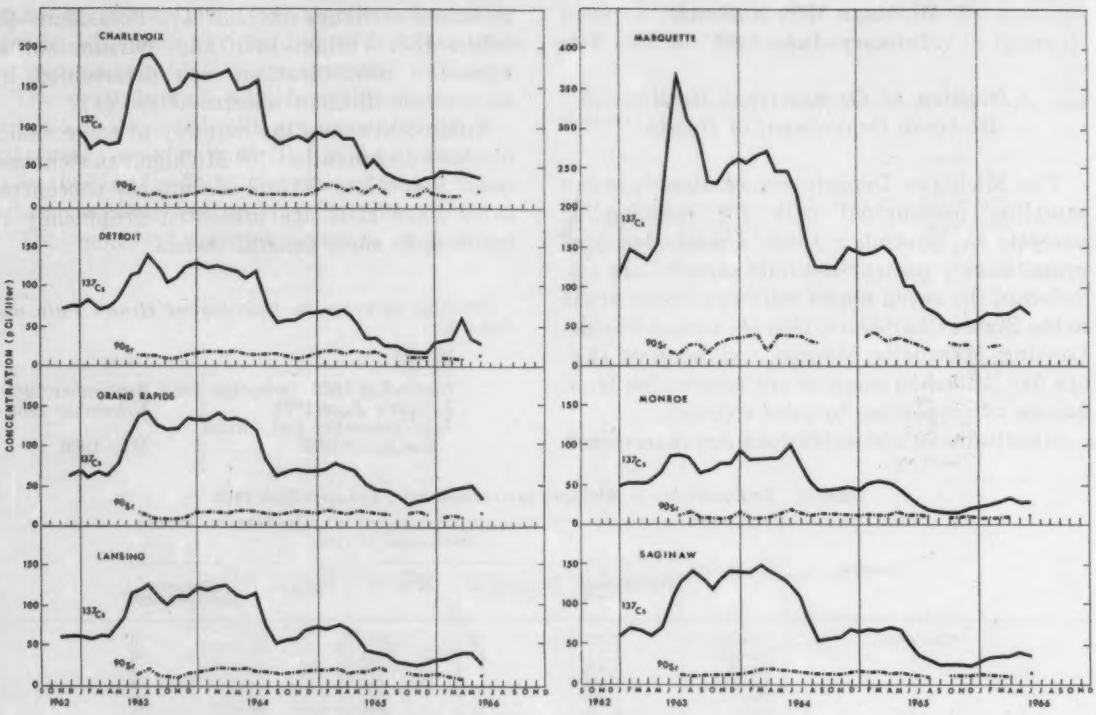

Figure 6. Radionuclide concentrations in Michigan pasteurized milk, 1962–June 1966

4. Minnesota Milk Network April–June 1966

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor stron'ium–90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 7) and analyzed for strontium–90, iodine–131, and cesium–137. One-liter samples of processed Grade-A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health Department district offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned.

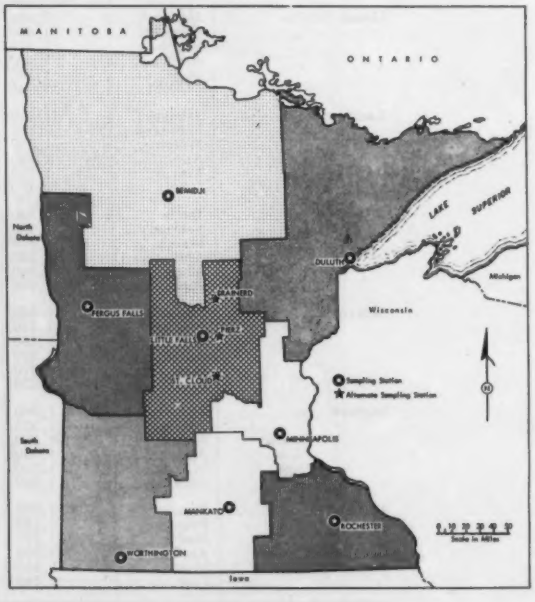

Figure 7. Minnesota milk sampling locations

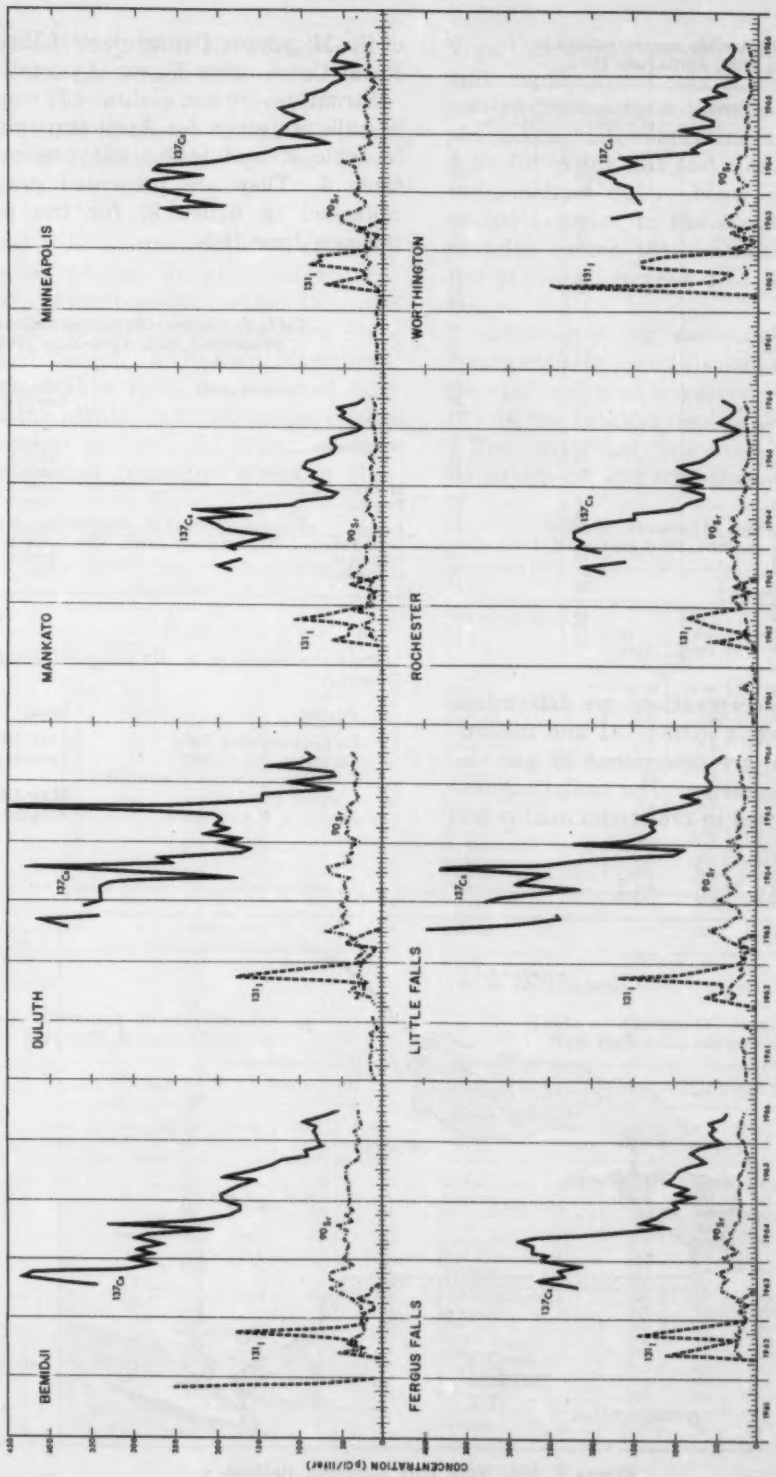

Figure 8. Radionuclide concentrations in Minnesota milk, 1961–June 1966

Table 4. Radionuclide concentrations in Minnesota milk, April–June 1966

Sampling location	Month 1966	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Bemidji	April	26	97
	May	29	67
	June	30	53
Mankato	April	12	62
	May	11	30
	June	12	25
Rochester	April	9	46
	May	15	29
	June	16	28
Duluth	April	31	96
	May	26	79
	June	34	93
Worthington	April	12	32
	May	13	30
	June	14	34
Minneapolis	April	17	57
	May	22	41
	June	16	43
Fergus Falls	April	16	60
	May	14	37
	June	14	32
Little Falls	April	19	67
	May	21	54
	June	18	41
Average	April	18	65
	May	19	46
	June	19	44

Strontium–90 concentrations are determined radiochemically, while iodine–131 and cesium–137 concentrations are determined by gamma-scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (*5*).

Strontium–90 and cesium–137 concentrations in milk are given for April through June 1966 in table 4, and iodine–131 concentrations in table 5. They are presented graphically by milkshed in figure 8, for the period 1962 through June 1966.

Table 5. Iodine-131 concentrations in Minnesota milk, April–June 1966

Collection point	Collection date 1966	Iodine-131 (pCi/liter)
Worthington	April 4	12
	May 1	13
	June 1	48
Mankato	June 1	51
Bemidji	June 6	12
Duluth	June 6	13
Little Falls	June 6	17
Rochester	June 6	24
Fergus Falls	June 8	13

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
July–December 1964	July 1965
January–June 1965	January 1966
July–December and annual summary 1965	May 1966
January–March 1966	August 1966

Figure 9. New York milk sampling stations

5. New York Milk Network January–June 1966

Division of Environmental Health Services
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 9) are analyzed for strontium–89, strontium–90, iodine–131, and barium-lanthanum–140 by the New York State Department of Health. At Buffalo, Newburgh, and Syracuse, milk samples are collected daily from processing plants, and composited weekly for radiochemical analysis. At Massena, samples are composited biweekly, while in New York City a milk sample representing the total milk supply for 1 day is obtained and composited weekly for analysis. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-emitting radionuclides in milk are determined by scintillation spectrometry and the application of a matrix method of analysis (*6*) to the resultant spectral data.

The analytical procedure for determining strontium–89 and strontium–90 concentrations

Table 6. Strontium-89 concentrations in New York milk, January–June 1966

Sampling location	Strontium-89, pCi/liter					
	January	February	March	April	May	June
Albany	NA	NA	<3	<3	<3	6
Ashford	<3	NS	NS	NS	NS	NA
Bedford	NS	NS	NS	NS	NS	NS
Buffalo	<3	<3	NS	<3	<3	4
Clarktown	NS	NS	NS	NS	<3	<3
East Otto	NS	NS	NS	NA	NS	NS
Massena	NS	NS	NS	<3	<3	<3
Middleburg	NS	NS	<3	<3	<3	<3
Mount Pleasant	NS	NS	NS	NS	NS	NS
Newburgh	NS	NS	NS	<3	<3	5
New York	<3	7	NS	<3	<3	7
Oyster Bay	NS	NS	NS	NS	<3	<3
Syracuse	NS	NS	NS	<3	5	6
Yaphank	NS	NS	NS	NS	NS	NS
Yorkshire	NS	NS	NS	NS	NS	NS
Yorktown	NS	NS	NS	NS	NS	NS
Average	<3	5	<3	<3	<3	4

NA, no analysis.
NS, no sample collected.

Table 7. Strontium-90 concentrations in New York milk, January–June 1966

Sampling location	Strontium-90, pCi/liter					
	January	February	March	April	May	June
Albany	NA	NA	6	5	9	10
Ashford	12	NS	NS	NS	NS	NA
Bedford	NS	NS	NS	NS	NS	NS
Buffalo	8	14	NS	6	9	8
Clarktown	NS	NS	NS	NS	<3	10
East Otto	NS	NS	NS	NA	NS	NS
Massena	NS	NS	NS	9	9	12
Middleburg	NS	NS	8	9	8	9
Mount Pleasant	NS	NS	NS	NS	NS	NS
Newburgh	NS	NS	NS	9	9	14
New York	12	7	NS	14	13	16
Oyster Bay	NS	NS	NS	NS	9	10
Syracuse	NS	NS	NS	8	6	8
Yaphank	NS	NS	NS	NS	NS	NS
Yorkshire	NS	NS	NS	NS	NS	NS
Yorktown	NS	NS	NS	NS	NS	NS
Average	11	11	7	9	8	11

NA, no analysis.
NS, no sample collected.

Table 8. Iodine-131 concentrations in New York milk, January–June 1966

Sampling location	Iodine-131, pCi/liter					
	January	February	March	April	May	June
Albany	<20	<20	<20	<20	<20	<20
Ashford	NA	NS	NS	NS	NS	<20
Bedford	NS	NS	NS	NS	NS	NS
Buffalo	<20	<20	NS	<20	<20	<20
Clarktown	NS	NS	NS	NS	<20	<20
East Otto	NS	NS	NS	<20	NS	NS
Massena	NS	NS	NS	<20	<20	NS
Middleburg	NS	NS	<20	<20	<20	<20
Mount Pleasant	NS	NS	NS	NS	NS	NS
Newburgh	NS	NS	NS	<20	<20	<20
New York	<20	<20	NS	<20	<20	<20
Oyster Bay	NS	NS	NS	NS	<20	<20
Syracuse	NS	NS	NS	<20	<20	<20
Yaphank	NS	NS	NS	NS	NS	NS
Yorkshire	NS	NS	NS	NS	NS	NS
Yorktown	NS	NS	NS	NS	NS	NS
Average	<20	<20	<20	<20	<20	<20

NA, no analysis.
NS, no sample collected.

Table 9. Cesium-137 concentrations in New York milk, January–June 1966

Sampling location	Cesium-137, pCi/liter					
	January	February	March	April	May	June
Albany	24	26	30	37	31	26
Ashford	NA	NS	NS	NS	NS	28
Bedford	NS	NS	NS	NS	NS	NS
Buffalo	24	44	NS	52	29	<20
Clarktown	NS	NS	NS	NS	<20	<20
East Otto	NS	NS	NS	43	NS	NS
Massena	NS	NS	NS	55	53	NS
Middleburg	NS	NS	36	74	34	22
Mount Pleasant	NS	NS	NS	NS	NS	NS
Newburgh	NS	NS	NS	<20	<20	<20
New York	43	22	NS	36	38	38
Oyster Bay	NS	NS	NS	NS	56	47
Syracuse	NS	NS	NS	22	37	23
Yaphank	NS	NS	NS	NS	NS	NS
Yorkshire	NS	NS	NS	NS	NS	NS
Yorktown	NS	NS	NS	NS	NS	NS
Average	30	31	33	42	40	28

NA, no analysis.
NS, no sample collected.

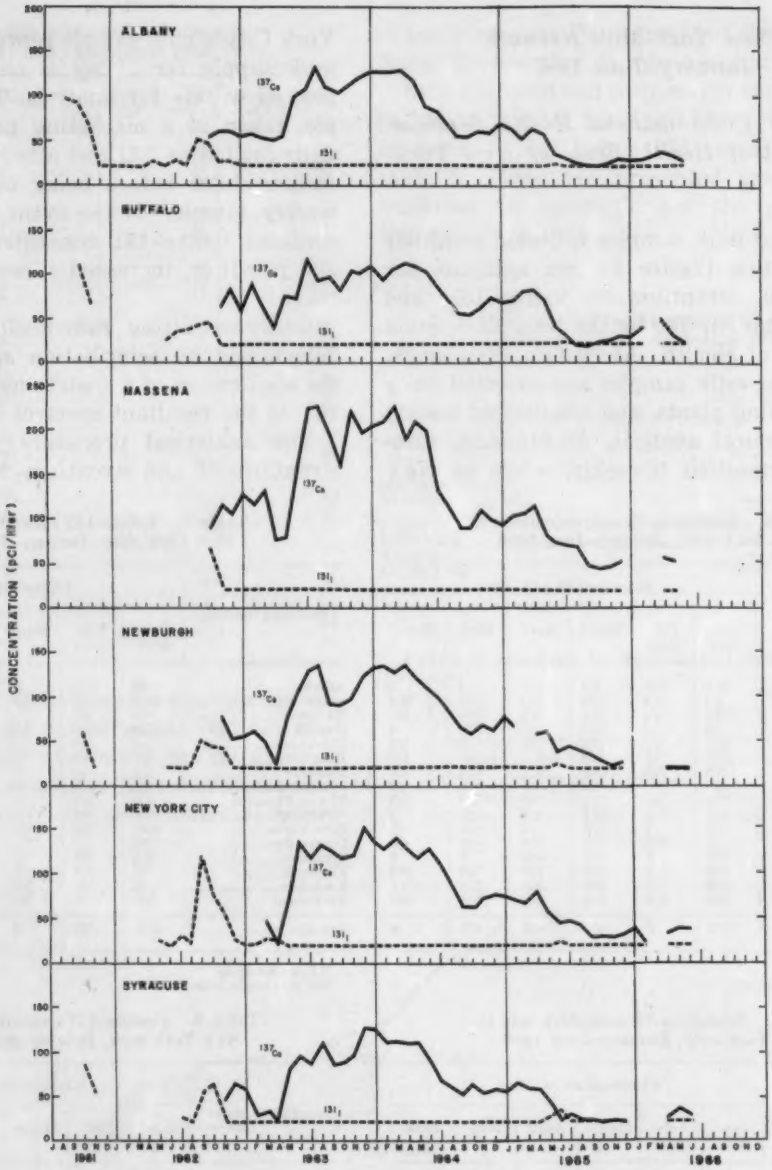

Figure 10. Radionuclide concentrations in New York milk, 1961–June 1966

employs an ion exchange system similar to that developed by Porter and Kahn (*2*).

The monthly average radionuclide concentrations of strontium–89 (table 6), strontium–90 (table 7), iodine–131 (table 8), and cesium–137 (table 9) are shown for January through June 1966. Iodine–131 and cesium–137 concentrations since September 1961 are presented graphically in figure 10.

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
July–September 1964	April 1965
October–December 1964	May 1965
Annual summary 1965	May 1966

6. Pennsylvania Milk Network April–June 1966

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 11). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location, subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health, in Harrisburg, where the weekly samples are combined for monthly analysis. Strontium–90 analyses have been carried out since April 1963.

The chemical separation technique for strontium–90 is essentially an ion exchange method described by Porter and Kahn (*2*).

The monthly average potassium–40, strontium–90, iodine–131, and cesium–137 concentrations in pasteurized milk are given in table 10. For comparative purposes, strontium–90, iodine–131, and cesium–137 concentrations are presented graphically in figure 12.

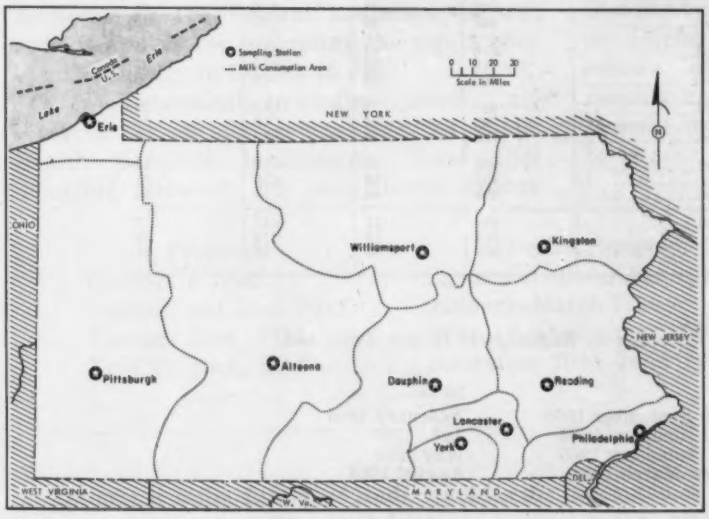

Figure 11. Pennsylvania pasteurized milk network sampling locations

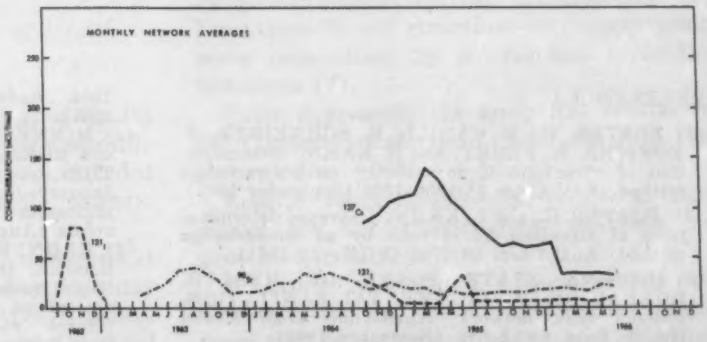

Figure 12. Radionuclide concentrations in Pennsylvania pasteurized milk, 1962–June 1966

Table 10. Radionuclide concentrations in Pennsylvania milk, April–June 1966

Sampling location	Month	Concentrations, pCi/liter			
		Potassium-40	Strontium-90	Iodine-131	Cesium-137
Altoona	April	850	15	<10	32
	May	800	22	<10	24
	June	910	14	10	27
Dauphin	April	865	12	<10	26
	May	810	14	<10	37
	June	889	16	10	22
Erie	April	885	25	<10	49
	May	926	22	<10	55
	June	890	30	10	38
Kingston	April	893	15	<10	32
	May	918	25	<10	35
	June	890	27	10	50
Lancaster	April	910	10	<10	24
	May	905	15	<10	33
	June	899	16	10	23
Philadelphia	April	750	10	<10	28
	May	894	13	<10	33
	June	900	11	10	26
Pittsburgh	April	896	21	<10	41
	May	928	29	<10	45
	June	882	20	10	36
Reading	April	920	12	<10	26
	May	919	17	<10	27
	June	800	12	10	30
Williamsport	April	825	15	<10	28
	May	792	14	<10	25
	June	790	18	15	29
York	April	900	13	<10	32
	May	891	16	<10	21
	June	890	14	10	28
Average	April	569	15	<10	32
	May	878	19	<10	34
	June	874	18	11	31

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
August–September 1964	February 1965
Annual summary 1964	June 1965
Annual summary 1965	May 1966
January–March 1966	August 1966

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(1) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determination of strontium-90 in milk by an ion-exchange method. Anal Chem 33:1306–1308 (September 1961).

(2) PORTER, C., and B. KAHN. Improved determinations of strontium-90 in milk by an ion-exchange method. Anal Chem 36:676–678 (March 1964).

(3) INDIANA STATE BOARD OF HEALTH, BUREAU OF ENVIRONMENTAL SANITATION. Indiana milk network, April–June 1965. Radiol Health Data 6:612–614 (November 1965).

(4) MICHIGAN DEPARTMENT OF HEALTH. Michigan milk network, November 1962–December 1964. Radiol Health Data 6:487–492 (September 1965).

(5) MINNESOTA DEPARTMENT OF HEALTH and RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January–June 1965, semiannual report, COO–615–17. Minnesota Department of Health, Minneapolis, Minnesota (August 1965).

(6) KAHN, B., G. K. MURTHY, C. PORTER, G. R. HAGEE, G. J. KARCHES, and A. S. GOLDIN. Rapid methods for estimating fission product concentrations in milk, PHS Publication No. 999–R–2 (March 1963). Single copies available on request from Public Inquiries Branch, PHS, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

FOOD AND DIET SURVEILLANCE ACTIVITIES

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in routine operation and reported periodically include: (1) the Public Health Service's Institutional Total Diet Sampling Network, (2) the Atomic Energy Commission's Tri-City Diet Study, (3) the Food and Drug Administration's Teenage Diet Study, (4) the State of California's Diet Study, and (5) the State of Connecticut's Standard Diet Study. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health and Reports* and not covered in this issue are listed below:

Program	Period reported	Last presented
California Diet	September–December 1965	September 1966
Institutional Diet, PHS	January–March 1966	October 1966
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	November 1965–January 1966	September 1966

1. Estimated Daily Intake of Radionuclides in Connecticut Standard Diet, July 1965–June 1966

Connecticut State Department of Health

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. These analyses included strontium–89, strontium–90, and gamma-emitting radionuclides.

The standard diet was selected to represent the food intake of an 18-year-old boy for 1 day (table 1). The total weight of the complete blended diet, averaging 3 kilograms, included milk and dairy products. When raw fruit or vegetables were sampled, they were washed before blending.

Cesium–137 concentrations were determined by gamma-scintillation spectrometry (*1*). Strontium–89 and strontium–90 concentrations were determined by a chemical separation technique (*1*).

Table 2 presents the analytical results for the Connecticut standard diet from July 1965 through June 1966.

Results representative of the total daily intake for the radionuclides observed are presented in table 3.

In order to evaluate general trends, the strontium–90 and cesium–137 daily intakes from 1963 to the present are plotted as a function of time in figures 1 and 2.

Table 1. Foods included in standard diet

Bread, white—8 slices	Ice cream—½ pint
Butter—½ stick	Lettuce, washed—4–5 leaves
Carrots, scraped—½ cup	Milk—3 cups
Celery, washed and trimmed—3 stalks	Oatmeal, uncooked—43 grams
Cookies—4	Orange—1
Cottage cheese—⅓cup	Peanut butter—2½ tablespoons
Cupcakes—2	Pears, canned—2 halves with juice
Egg—1	Potatoes, washed, not peeled—2
Green beans, washed—½ cup	Sugar—5 tablespoons
Ham—85 grams	Tomato juice—113 grams
Hamburger—227 grams	Tuna fish, drained—43 grams

Table 2. Radionuclide concentrations in Connecticut standard diet, July 1965–June 1966 [a]

Month	Potassium (g/kg)	Strontium-90 (pCi/kg)	Cesium-137 (pCi/kg)
1965			
July	2.0	NA	60
August	2.0	13.9	70
September	2.2	12.7	50
October	2.2	16.3	60
November	2.2	11.0	50
December	2.2	11.3	30
1966			
January	2.1	10.7	50
February	2.3	12.4	30
March	2.4	12.3	60
April	2.4	14.1	40
May	2.4	10.4	30
June	2.3	16.3	40

[a] All strontium-89 values <3 pCi/kg for this period.
NA, no analysis performed.

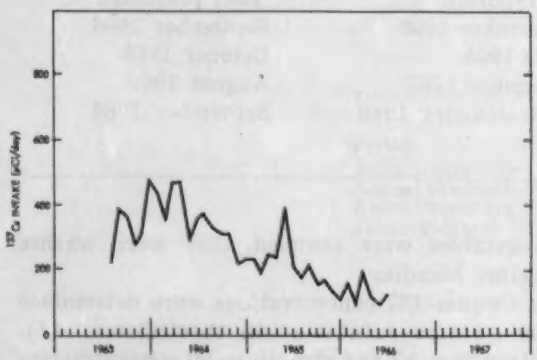

Figure 1. Cesium-137 intake in Connecticut standard diet 1963–June 1966

Table 3. Daily radionuclide intakes in Connecticut standard diet, July 1965–June 1966 [a]

Month	Potassium (g/day)	Strontium-90 (pCi/day)	Cesium-137 (pCi/day)
1965			
July	5.7	NA	180
August	6.2	43.1	220
September	6.8	39.2	160
October	6.5	47.9	170
November	6.6	33.4	140
December	7.1	37.0	110
1966			
January	6.2	31.8	160
February	7.4	40.8	90
March	7.4	38.3	200
April	7.3	42.3	130
May	7.4	31.9	100
June	7.3	31.5	130

[a] All strontium-89 values <3 pCi/day for this period.
NA, no analysis performed.

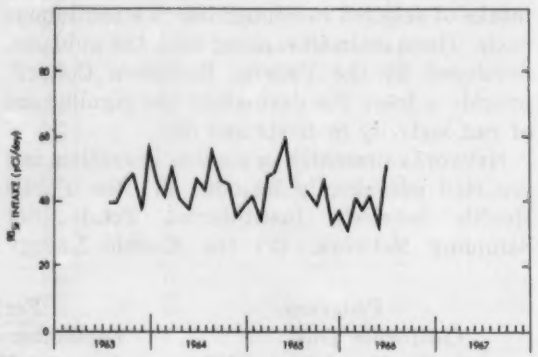

Figure 2. Strontium-90 intake in Connecticut standard diet 1963–June 1966

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
March 1963–December 1964	July 1965
January–June 1965	February 1966

REFERENCE

(*1*) CONNECTICUT STATE DEPARTMENT OF HEALTH. Estimated daily intake of radionuclides in Connecticut standard diet, March 1963–December 1964. Radiol Health Data 6:381–382 (July 1965).

Section II. Water

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross alpha and gross beta radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha emitters, the limit is 1,000 pCi/liter gross beta activity, except when more complete analysis indicates that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides. Surveillance data from a number of Federal and State programs published periodically in *Radiological Health Data and Reports* are listed below:

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha emitters and strontium–90, respectively.

Program	Period reported	Last presented
Colorado River Basin Sampling Network	1962–1964	November 1965
Drinking Water Analysis Program	1962	October 1965
Florida Water Sampling Program	1964	November 1965
Kentucky Water Sampling Program	May 1963–June 1964	March 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Minnesota Surface Water Sampling Program	July–December 1965	July 1966
New York Water Sampling Program	June–December 1965	June 1966
North Carolina Water Sampling Program	1964	November 1965
Radiostrontium in Tap Water, HASL	May and July–November 1965	June 1966
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, MAY 1966

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as a part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha and beta analyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported quarterly. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations are published in annual compilations (*1–6*) or are available on request.

Special note is taken when the alpha radio-

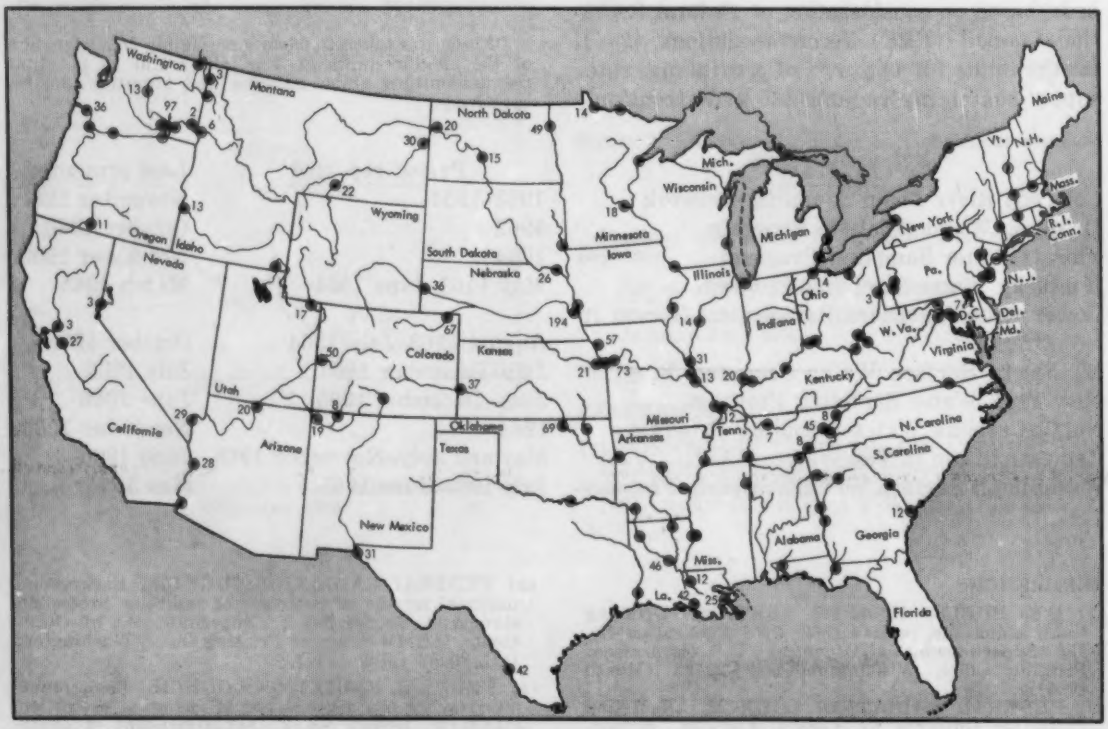

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, May 1966

activity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During April and May the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved solids:

North Platte River: Henry, Nebraska
South Platte River: Julesburg, Colorado

Coolidge, Kansas, on the Arkansas River, dropped to 12 pCi/liter of alpha radioactivity

Table 1. Radioactivity in raw surface waters, May 1966

Stations	Average beta activity (pCi/liter)			Average alpha activity (pCi/liter)			Stations	Average beta activity (pCi/liter)			Average alpha activity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:							North Platte River:						
Cedar Hill, N. Mex.	4	4	8	1	1	2	Henry, Nebr.	2	34	36	<1	19	19
Arkansas River:							Ohio River:						
Coolidge, Kans.	3	34	37	<1	12	12	Toronto, Ohio	0	3	3	0	0	0
Ponca City, Okla.	38	31	69	6	3	9	Cairo, Ill.	4	8	12	1	0	1
Atchafalaya River:							Pend Oreille River:						
Morgan City, La.	34	8	42	9	1	10	Albeni Falls Dam, Idaho	0	3	3	0	<1	<1
Big Horn River:							Platte River:						
Hardin, Mont.	3	19	22	<1	10	10	Plattsmouth, Nebr.	171	23	194	43	5	48
Chena River:							Potomac River:						
Fairbanks, Alaska	8	5	13	1	1	2	Washington, D.C.	3	4	7	1	0	1
Clearwater River:							Rainy River:						
Lewiston, Idaho	4	2	6	<1	0	<1	Baudette, Minn.	3	11	14	<1	0	<1
Clinch River:							Red River, North:						
Clinton, Tenn.	5	3	8	1	0	1	Grand Forks, N. Dak.	11	38	49	1	4	5
Kingston, Tenn.[a]	2	43	45	0	<1	<1	Red River, South:						
Colorado River:							Alexandria, La.	37	9	46	7	0	7
Loma, Colo.	37	13	50	10	4	14	Rio Grande:						
Page, Ariz.	<1	20	20	0	6	6	El Paso, Tex.	11	20	31	3	3	6
Boulder City, Nev.	1	28	29	0	10	10	Laredo, Tex.	28	14	42	10	3	13
Parker Dam, Calif-Ariz.	1	27	28	0	9	9	Sacramento River:						
Columbia River:							Greens Landing, Calif.	1	2	3	0	0	0
Wenatchee, Wash.	10	3	13	0	0	0	San Joaquin River:						
Pasco, Wash.[a]	45	52	97	<1	1	1	Vernalis, Calif.	13	14	27	3	9	12
Clatskanie, Ore.	7	29	36	0	0	0	San Juan River:						
Cumberland River:							Shiprock, N. Mex.	11	8	19	4	3	7
Cheatham Lock, Tenn.	3	4	7	1	0	1	Savannah River:						
Green River:							Port Wentworth, Ga.[a]	2	10	12	0	0	0
Dutch John, Utah	1	16	17	0	3	3	Snake River:						
Illinois River:							Payette, Idaho	2	11	13	<1	4	4
Peoria, Ill.	3	11	14	1	1	2	Wawawai, Wash.	0	2	2	0	0	0
Grafton, Ill.	4	27	31	0	2	2	South Platte River:						
Kansas River:							Julesburg, Colo.	2	65	67	0	40	40
DeSoto, Kans.	2	19	21	1	2	3	Tennessee River:						
Klamath River:							Chattanooga, Tenn.	1	7	8	0	0	0
Keno, Ore.	1	10	11	0	<1	<1	Truckee River:						
Maumee River:							Farad, Calif.	1	2	3	0	0	0
Toledo, Ohio	2	12	14	1	1	2	Wabash River:						
Mississippi River:							New Harmony, Ind.	8	12	20	2	1	3
St. Paul, Minn.	2	16	18	0	2	2	Yellowstone River:						
E. St. Louis, Ill.	2	11	13	1	1	2	Sidney, Mont.	19	11	30	5	3	8
New Roads, La.	3	9	12	0	0	0							
New Orleans, La.	16	9	25	4	0	4	Maximum	171	65	194	43	40	48
Missouri River:													
Williston, N. Dak.	6	14	20	2	4	6	Minimum	0	2	2	0	0	0
Bismarck, N. Dak.	1	14	15	0	2	2							
Yankton, S. Dak.	1	25	26	0	4	4							
St. Joseph, Mo.	37	20	57	5	4	9							
Kansas City, Kans.	50	23	73	10	5	15							

[a] Gross beta activity at this station may not be directly comparable to gross beta activity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides common to all stations.

on dissolved solids. Plattsmouth, Nebraska, on the Platte River showed an increase in alpha radioactivity on suspended solids to greater than 15 pCi/liter.

During May, Pasco, Washington, on the Columbia River, has decreased in beta radioactivity on dissolved solids to less than 150 pCi/liter. At Kingston, Tennessee, on the Clinch River, the beta radioactivity on dissolved solids has decreased to nearly normal levels for the monthly average as well as for all of the weekly samples.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(*2*) *Ibid.*, 1959 Edition.
(*3*) *Ibid.*, 1960 Edition.
(*4*) *Ibid.*, 1961 Edition.
(*5*) *Ibid.*, 1962 Edition.
(*6*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

RADIONUCLIDE ANALYSIS OF COAST GUARD WATER SUPPLIES JANUARY–DECEMBER 1965

U.S. Coast Guard [1] *and*
Division of Radiological Health [2]

Beginning in October 1961, 1-gallon samples of water have been obtained from seven Coast Guard Loran Stations in Alaska (figure 1).

The prime source of potable water at the Adak Loran Station is Alpine Lake, which is at an elevation of 1,000 feet. The lake is occasionally frozen over with little snow cover each year from December through April. Water is delivered from the lake as needed through a 2-mile pipe line to three 25,000-gallon concrete reservoirs. All water is chlorinated at the station before use.

The Attu Loran Station's prime source of potable water is Alout Creek Dam and reservoir. This water source is usually frozen over from November through April, with a frequent snow cover of 1 to 3 feet. A 1-mile pipe line feeds water by gravity to three 25,000-gallon concrete reservoirs at the station. The water is chlorinated before use.

The Biorka Loran Station's water comes from a lake that is often frozen over lightly from January to March. The water is fed by

[1] U.S. Department of the Treasury
[2] U.S. Public Health Service

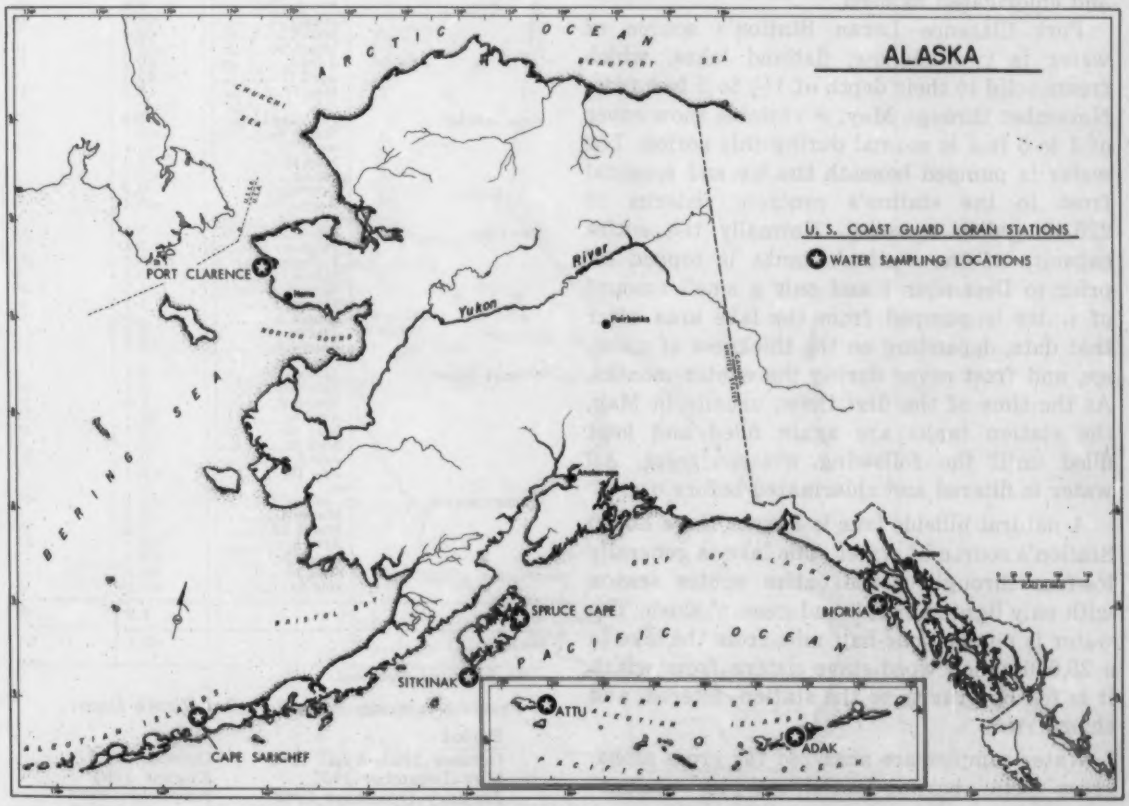

Figure 1. Coast Guard Loran station water sampling locations

gravity through a 1-mile-long insulated pipe to a pump house. From there it is pumped another mile to a 25,000-gallon steel storage tank from which it is fed by gravity one-half mile to the station, filtered, and chlorinated.

The source of water for the Cape Sarichef Loran Station is a small dammed creek and reservoir. The reservoir is usually frozen over from December through April, with 1 to 3 feet of snow cover during that period. The water is pumped 1½ miles from the dam to a 25,000-gallon steel storage tank above ground, from which the water is fed by gravity to the station, filtered and chlorinated.

The Sitkinak Loran Station obtains its water from a natural lake which is normally frozen over from December through April, with 3 to 12 inches of snow cover during that period. The water is pumped from the lake through a 1,500-foot line to three 25,000-gallon concrete reservoirs at the station. The water is filtered and chlorinated as used.

Port Clarence Loran Station's source of water is two shallow, flatland lakes, which freeze solid to their depth of 1½ to 3 feet from November through May. A variable snow cover of 1 to 5 feet is normal during this period. The water is pumped beneath the ice and seasonal frost to the station's concrete cisterns of 225,000-gallon capacity. Normally the entire capacity of the station's tanks is topped off prior to December 1 and only a small amount of water is pumped from the lake area after that date, depending on the thickness of snow, ice, and frost cover during the winter months. At the time of the first thaw, usually in May, the station tanks are again filled and kept filled until the following winter freeze. All water is filtered and chlorinated before use.

A natural hillside lake is Spruce Cape Loran Station's source of water. The lake is generally ice-free throughout the entire winter season with only light snowfall and general slush. The water is pumped one-half mile from the lake to a 25,000-gallon wood-stave cistern from which it is fed by gravity to the station, filtered, and chlorinated.

Water samples are analyzed for gross alpha, gross beta, barium-lanthanum–140, cesium–137, iodine–131, ruthenium–103, ruthenium–106, and zirconium-niobium–95. The radionuclide analyses are performed by gamma spectrometry. All analyses are performed by the Southwestern Radiological Health Laboratory, Las Vegas, Nevada. The results of the gross alpha and beta analyses are reported in table 1. Values for specific radionuclide content are not reported, since in all cases they were below the respective minimum detectable levels (cesium–137, 5 pCi/liter; all others, 10 pCi/liter).

Table 1. Radioactivity in water samples from U.S. Coast Guard Loran stations January–December 1965

Alaskan location	Collection date 1965	Gross alpha (pCi/liter)	Gross beta (pCi/liter)
Adak	February 23	NA	3
Attu Island	May 7	0.1	13
	June 4	<0.1	8
	July 13	0.4	4
	July 15	0.3	6
Biorka Island	January 13	NA	23
	January 19	NA	3
	January 26	NA	5
	February 16	NA	24
	February 23	NA	26
	March 16	<0.1	14
	March 24	<0.1	7
	March 30	<0.1	18
	April 5	<0.1	11
	April 13	<0.1	3
	May 17	<0.1	17
Cape Sarichef	February 11	NA	3
	March 9	<0.1	2
	April 23	<0.1	8
	May 18	<0.1	3
	June 4	<0.1	2
	July 6	0.2	2
	August 12	<0.1	4
Port Clarence	January 16	NA	14
	February 17	NA	2
	February 18	NA	12
	March 12	0.8	8
	April 8	1.1	28
	May 6	1.1	18
	June 3	1.9	14
	July 6	0.2	5
	August 3	<0.1	18
Sitkinak Island	January 13	NA	3
	February 13	NA	16
	March 9	0.3	20
	April 8	<0.1	17
	May 10	<0.1	16
	May 16	<0.1	5
	July 6	0.4	20
	July 15	<0.1	7
Spruce Cape	January 12	<0.1	<1
	March 8	0.2	4
	March 29	0.8	11
	April 6	<0.1	11
	May 3	<0.1	7
	June 24	<0.1	4
	July 23	<0.1	15
Maximum		1.9	28
Minimum		<0.1	<1

NA, no analysis performed.

Previous coverage in *Radiological Health Data*:

Period	Issue
October 1961–April 1962	October 1962
May–December 1962	August 1963
January–December 1963	November 1964
January–December 1964	November 1965

RADIOACTIVITY IN CALIFORNIA WATERS JULY–DECEMBER 1965[1]

Bureau of Radiological Health
State of California Department of Public Health

Gross beta activity in California domestic waters is monitored by the State of California's Bureau of Radiological Health. The importance of this program in the State's environmental surveillance activities stems from the fact that most of California's domestic water supplies are of surface origin.

[1] Data from January and April 1966 issues of Radiological Health News, State of California Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley 4, California.

Radioactivity in such water supplies consists of the natural radioactivity in surface streams, radioactivity added by the discharge of sewage or by industrial waste effluents, and radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Present efforts consist of sampling raw and treated surface waters and well waters. It should be noted that except for large metropolitan water supplies, raw water sampling is

Figure 1. California surface water sampling stations

being phased out and treated water sampling being substituted or continued. This procedural change is predicated upon sampling water at the point of consumption.

Most of the supplies sampled have as a source, raw surface waters (figure 1), although a few wells, along with some water supplies that use infiltration galleries, are also sampled.

Monitoring of domestic water supplies is on a continuing basis, since it has not been possible

Table 1. Gross beta activity in California domestic waters, July–December 1965

Sampling station	Quality	Concentration, pCi/liter					
		July	Aug	Sept	Oct	Nov	Dec
Alturas	Well	*9	*5	*6	*12	*12	*15
Antioch	Treated	NS	*13	ND	*2	*6	*8
Lake Arrowhead	Raw	NS	*3	NS	*15	*13	NS
Berkeley	Treated	ND	*1	*12	ND	ND	*13
Clearlake Highlands	Treated	*5	ND	*8	NS	ND	*8
Crescent City	Well	*1	ND	ND	*7	ND	*3
Death Valley	Treated	*16	ND	*2	*20	*21	ND
Dos Palos	Treated	*7	*10	*11	ND	*8	ND
El Centro	Treated	*1	ND	*6	ND	*6	*19
Eureka	Raw	*15	ND	ND	*2	ND	*12
	Treated	*7	ND	*3	ND	*14	*12
Fort Bragg	Treated	ND	NS	NS	NS	*12	*2
Los Angeles Laboratory	Treated	*24	ND	*12	ND	*4	NS
Marin Municipal Water District	Treated	ND	ND	*7	ND	ND	ND
Mariposa	Raw	ND	ND	*17	NS	*8	*13
Metropolitan Water District of Southern California:							
Lake Havasu	Raw	NS	*2	ND	NS	*21	*14
Weymouth Plant	Treated	*19	ND	*6	*7	*18	31
Lake Millerton	Raw	*5	*13	*1	ND	*10	*13
Monterey	Treated	*1	ND	*17	ND	NS	NS
Napa	Raw	ND	NS	NS	NS	*2	*4
Needles	Well	*11	ND	*2	*30	*5	*4
North Marin Water District	Treated	*21	*10	*9	*14	*11	*6
	Raw	*14	*17	ND	*8	ND	*13
	Sludge [b]	*41	ND	*13	*7	ND	*29
Oroville:							
California Water Service	Treated	*5	*7	ND	*3	*1	*7
Wyandotte Irrigation District	Treated	ND	ND	ND	*11	ND	*7
Pleasanton	Well	NS	NS	ND	ND	ND	ND
Redding	Treated	NS	NS	NS	NS	NS	NS
Sacramento	Treated	96	17	*23	*3	ND	NS
Salinas	Well	NS	ND	NS	NS	ND	NS
San Diego	Raw	*16	*3	ND	ND	ND	*19
	Treated	*6	ND	ND	*19	*16	*3
San Francisco:							
Water Department	Raw	*4	ND	ND	*6	*7	*2
Alameda, East	Raw	*5	*6	19	*10	*12	NS
Brightside Weir	Raw	ND	*2	*4	ND	NS	NS
Calaveras Reservoir	Raw	ND	ND	ND	ND	*3	NS
Crystal Springs	Raw	ND	*5	ND	ND	*1	NS
Hetch Hetchy	Raw	24	*17	*19	*4	ND	NS
San Jose	Raw	ND	ND	NS	NS	NS	NS
	Treated	NS	NS	NS	ND	ND	*4
San Luis Obispo	Treated	NS	NS	*8	ND	NS	ND
Santa Barbara	Treated	*18	*4	*8	ND	*13	ND
Santa Cruz	Raw	NS	ND	NS	NS	NS	NS
	Treated	ND	NS	NS	*12	*1	NS
Santa Rosa	Well	ND	ND	ND	*5	*3	*5
Scotia	Treated	NS	NS	NS	NS	*2	NS
Tahoe City	Raw	NS	*9	NS	NS	NS	*19
Ukiah	Well	*6	*8	*1	ND	*4	NS
Vallejo:							
Fleming Hill	Raw	*2	*4	ND	ND	*9	*3
	Treated	*4	*5	35	ND	ND	ND
Swanzy Reservoir	Treated	ND	*11	ND	ND	*15	*2
Willits	Treated	*7	ND	ND	*6	*2	*9
Yosemite	Treated	*8	*5	NS	NS	*10	NS
Maximum		96	17	35	30	21	31
Minimum		1	1	1	2	1	2

* When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best estimate, but is not statistically significant.
[b] Sludge reported in pCi/g (dry weight).
NS, no sample collected.
ND, no detectable activity.

Table 2. Radionuclide concentrations in California surface water 1962–1965

Sampling station and date	Concentration, pCi/liter						
	Potassium-40	Manganese-54	Zirconium-niobium-95	Cesium-137	Cerium-141-cerium-144	Strontium-89	Strontium-90
Antioch							
December 1963–May 1964	2.6	0.6	ND	0.2	ND	*0.9	2.4
July–December 1964	*1.4	*0.2	ND	0.8	0.0	0.0	0.3
January–July 1965	*1.6	*0.1	*0.1	*0.1	0.0	NA	1.0
Berkeley							
July–December 1963	2.6	ND	0.3	0.3	ND	48.0	1.1
January–June 1964	5.2	0.9	2.8	0.5	0.6	*2.0	1.5
July–December 1964	13.0	0.0	0.0	1.0	ND	NA	1.1
January–June 1965	*0.6	*0.2	ND	0.3	*0.2	NA	0.9
Chula Vista							
February–July 1963	*2.7	2.2	ND	0.5	ND	*14.6	0.7
August 1963–January 1964	6.4	0.6	*0.4	0.5	0.5	*0.2	1.7
Clear Lake							
June–December 1963	3.7	ND	25.2	ND	0.6	*0.7	2.7
Crescent City							
June–December 1963	3.0	0.4	*0.6	0.2	0.3	ND	0.1
July–December 1964	*0.5	ND	ND	*0.1	*0.2	0.0	0.2
Dos Palos							
July 1963–January 1964	2.3	ND	4.2	1.0	ND	4.5	0.9
May–August 1964	*0.3	*0.2	ND	*0.1	0.4	0.0	0.4
October 1964–January 1965	*3.3	*0.5	*0.1	*0.3	*0.7	NA	0.6
May–September 1965	*1.4	*0.1	ND	0.2	ND	NA	NA
El Centro							
May–October 1962	ND	ND	ND	ND	ND	ND	*2.6
November 1962–April 1963	3.8	0.7	ND	*0.1	10.7	ND	*0.5
May–July 1963	*1.2	3.5	ND	3.3	3.6	ND	0.6
September 1963–March 1964	4.9	1.1	ND	1.0	0.3	NA	1.3
April–October 1964	12.0	3.1	ND	0.8	83.0	NA	1.4
November 1964–May 1965	*1.4	*0.4	ND	0.4	*0.6	NA	1.7
Eureka							
January–June 1963	3.4	*0.2	*0.9	0.2	0.4	NA	0.1
July–December 1963	ND	ND	*7.4	ND	ND	ND	0.3
January–June 1964	22.5	16.6	53.3	17.7	46.9	6.2	7.8
July–December 1964	*1.0	ND	ND	1.6	ND	NA	0.2
Marin Municipal Water District							
June–October 1963	*3.3	1.0	*2.4	ND	5.3	ND	1.2
November 1963–March 1964	3.8	*0.1	1.5	ND	0.3	*1.0	0.9
March–August 1964	5.3	*0.4	ND	*0.4	3.0	0.0	0.9
Metropolitan Water District of Southern California							
Lake Matthews							
July–December 1963	ND	0.6	2.2	0.2	1.5	*0.5	1.1
Weymouth Plant							
January–June 1964	*1.0	ND	ND	ND	0.3	ND	0.4
July–December 1964	ND	ND	ND	NA	ND	0.0	1.8
Millerton Lake							
July–December 1963	NA	NA	NA	NA	NA	*0.8	0.9
January–June 1964	*0.5	ND	ND	0.6	ND	0.0	1.0
July–December 1964	*1.2	*0.1	ND	0.4	ND	0.0	1.3
Monterey							
July 1963–January 1964	*1.8	0.6	ND	*0.1	ND	ND	0.3
January–June 1964	2.1	ND	*0.3	0.2	0.4	0.0	0.3
July–December 1964	*1.6	0.0	ND	ND	0.0	0.0	0.3
January–June 1965	5.2	*0.4	*0.4	*0.1	*0.4	NA	0.5
Napa							
October 1963–March 1964	4.8	ND	5.9	NA	0.3	NA	1.0
April–December 1964	*1.4	ND	ND	0.9	0.1	0.0	1.1
January–June 1965	*2.1	*0.2	ND	NA	0.7	NA	NA
North Marin Water District							
July–December 1963	3.3	ND	4.2	1.3	ND	ND	3.5
January–June 1964	3.8	ND	ND	0.2	*0.1	0.6	0.6
July–December 1964	5.0	*0.1	ND	*0.1	ND	0.0	2.5
January–June 1965	4.1	*0.2	ND	*0.1	*0.3	NA	1.3
Oroville							
California Water Service							
November 1964–March 1965	*0.4	*0.1	ND	0.2	ND	NA	NA
April–September 1965	*0.6	*0.1	ND	*0.1	*0.1	NA	NA
Wyandotte Irrigation District							
November 1964–March 1965	*0.2	*0.1	0.1	ND	ND	NA	1.0
April–September 1965	*0.9	*0.1	ND	0.2	ND	NA	NA
Redding							
July–December 1963	ND	0.6	2.0	0.5	1.9	ND	0.9
January–June 1964	ND	ND	1.0	0.2	2.0	*0.9	0.5
July–December 1964	*3.4	*0.7	1.0	1.0	0.1	0.8	0.8
January–June 1965	*0.9	*0.1	ND	*0.1	ND	NA	NA

See footnotes at end of table.

Table 2. Radionuclide concentrations in California surface water 1962–1965—Continued

Sampling station and date	Concentration, pCi/liter						
	Potassium-40	Manganese-54	Zirconium-niobium-95	Cesium-137	Cerium-141-cerium-144	Strontium-89	Strontium-90
Sacramento							
July–December 1963	2.7	ND	3.1	*0.2	0.7	NA	1.7
January–June 1964	*0.7	ND	ND	ND	0.4	0.0	2.9
July–December 1964	*1.0	*0.1	ND	*0.3	ND	0.0	0.8
January–October 1965	*1.6	ND	ND	*0.2	*0.2	NA	NA
San Diego							
May–November 1963	3.5	ND	0.4	0.8	2.4	*9.7	4.1
November 1963–June 1964	56.8	8.8	NA	12.7	NA	ND	4.8
July–December 1964	3.8	ND	ND	0.3	*0.1	0.0	1.1
January–June 1965	4.5	*0.2	ND	0.6	0.4	NA	0.3
San Francisco							
August 1963–February 1964	ND	0.5	2.4	0.2	0.7	7.5	1.1
February–October 1964	88.8	14.4	1.5	8.9	ND	0.0	1.5
San Jose							
January–June 1964	*0.8	*0.1	ND	*0.1	ND	*0.2	0.2
July–December 1964	*1.0	ND	1.2	1.4	ND	0.0	0.5
January–June 1965	*1.1	ND	ND	*0.1	ND	NA	0.3
Santa Barbara							
December 1962–June 1963	6.3	ND	23.4	0.4	9.7	*24.7	2.9
August 1963–February 1964	*0.3	0.3	5.7	ND	1.5	NA	2.6
March–December 1964	ND	5.8	3.5	10.5	NA	NA	9.8
October 1964–February 1965	ND	ND	ND	ND	ND	NA	1.1
March–July 1965	3.5	*0.1	ND	*0.3	0.7	NA	1.0
Santa Cruz							
January–July 1963	ND	ND	*0.6	ND	*0.5	ND	0.6
January–May 1964	3.8	*0.5	*3.6	ND	4.4	*1.3	3.1
May–November 1964	12.0	NA	NA	2.3	3.4	0.0	0.4
Santa Rosa							
July–December 1963	ND	0.5	2.4	ND	1.4	*0.4	0.2
January–June 1964	*0.5	0.4	ND	0.6	ND	ND	0.2
July–December 1964	*1.4	*0.3	*0.5	*0.1	0.0	0.0	0.1
January–June 1965	*0.2	*0.1	ND	ND	0.5	NA	0.2
Scotia							
July–December 1964	3.5	2.2	5.8	1.5	1.6	0.0	0.5
Tahoe City							
June–December 1964	ND	ND	ND	0.1	ND	0.0	0.3
January–June 1965	*1.5	ND	*0.4	0.3	ND	NA	0.3
Ukiah							
January–June 1964	7.8	ND	15.9	ND	1.6	0.0	0.4
Vallejo							
January–June 1965	*1.7	*0.2	ND	*0.1	*0.1	NA	1.2
Willits							
December 1963	7.5	0.9	5.0	0.3	2.2	*2.1	0.6
Yosemite							
July 1963–January 1964	4.5	1.4	12.5	0.4	1.4	11.5	1.5
January–December 1964	*0.8	ND	ND	*0.5	0.7	0.0	1.1
January–June 1965	*0.5	*0.2	*0.4	0.4	ND	NA	1.2

* When the counting rate of the sample is not equal to at least twice the 0.95 error the value reported is the best available estimate, but is not statistically significant.
ND, no detectable activity.
NA, no analysis reported.

to forecast levels of radioactivity in these supplies based upon levels in rain, snow, or surface streams. Under the present sampling schedule, monthly 500-ml samples are collected and the total solids analyzed for alpha and beta radioactivity. In addition, 3-liter samples are collected monthly for approximately 6 months and composited for specific radionuclide analysis on a semiannual basis.

Analytical procedures

Radionuclide analyses of water are carried out in the State's Sanitation and Radiation Laboratory. Measurements of alpha and alpha-plus-beta activities are made with a low-background, windowless gas-flow proportional counter. Counting methods used follow those recommended by the U.S. Public Health Service (*1*).

Individual samples are evaporated to dryness and the residue ashed at 450°C. The ashed sample is dissolved and transferred to an aluminum planchet for beta counting. Gamma-emitting radionuclides are determined annually on the composite samples.

Discussion

Table 1 shows the monthly average beta activity in the suspended-plus-dissolved solids in surface water supplies in California from July through December 1965. Following treatment, these waters are used for industrial and domestic purposes. Because alpha activity in water has, in general, been undetectable or very slight, alpha activity analyses are not presented. No increase in radioactivity level of surface water has been observed. Table 2 shows specific radionuclide concentrations in California surface waters semiannually by stations from 1962 to 1965. Data for 1960 to 1963 were published in the March 1965 issue of *Radiological Health Data.*

REFERENCE

(1) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analyses of environmental samples, R 59–6. Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (November 16, 1959).

Previous coverage in *Radiological Health Data and Reports*:

Period	Issue
1961–June 1962	April 1963
July–December 1962	September 1963
January–June 1963	March 1964
July–December 1963	September 1964
January–June 1964	March 1965
July–December 1964	September 1965
January–June 1965	March 1966

Section III. Air and Deposition

RADIOACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson (*1*) in 1962. In addition to the programs presented in this issue, the following program was previously covered in *Radiological Health Data and Reports:*

Program	Period reported	Last presented
HASL Fallout Network	July–December 1965	September 1966

1. Radiation Surveillance Network July 1966

Division of Radiological Health
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN), Division of Radiological Health, Public Health Service, which regularly gathers samples from 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators report (by telephone) field estimates greater than 10 pCi/m^3 (except for Hawaii, Alaska, and Puerto Rico, which report estimates greater than 5 pCi/m^3) to the Radiation Surveillance Center, Division of Radiological Health, Washington, D.C. Field estimates and laboratory measurements of daily concentrations and the estimated ages for selected samples are reported in the monthly RSN report (*2*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Figure 1. Radiation Surveillance Network sampling stations

Sampling and analytical procedures

Airborne particulates are collected continuously on carbon-loaded cellulose dust filters 4 inches in diameter. About 1,800 cubic meters of air are drawn through a filter during the 24-hour sampling period. The filters are forwarded to the RSN laboratory in Rockville, Maryland, where the gross beta activity is measured 4 days after the sampling period and again 7 days later if the net count rate is 2,000 cpm (approximately 1 pCi/m³). By using the two counts and the Way-Wigner formula (*3*), the age of fission products is estimated and the activity at time of collection determined.[1] Additionally, analyses for specific radionuclides may be performed.

The total precipitation is sampled continuously at most RSN stations on a daily basis, using funnels with collection area of 0.4 square meter. If the rainfall exceeds 0.2 inch, the precipitation sample is analyzed for gross beta activity (*2*). Additionally, analyses for specific radionuclides may be performed.

In the laboratory the gross beta activity in evaporated precipitation samples is calculated by the same method used for analyzing the air filters. Total deposition (D) is determined by the equation:

$$D\,(nCi/m^2) = \frac{\text{concen (pCi/liter} \times \text{pptn depth (mm)}}{1{,}000}$$

Selected air and precipitation samples are analyzed by gamma spectrometry to determine the presence of fresh fission products. The methods discussed by Burrus (*4*) and Covell (*5*) were adapted for resolving the complex gamma spectra.

Monthly values of gross beta activity in air, total deposition, and depth of precipitation are given in table 1 for July 1966. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2. Gamma spectroscopy analysis was performed on 305 air samples. No fresh fission products were positively identified on air samples during July 1966.

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value; consequently, the calculated age of the fresh component will be overestimated.

Table 1. Gross beta activity in surface air and precipitation, July 1966

Station location		Number of samples		Air surveillance (gross beta activity, pCi/m³)			Last profile in *RHD & R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	31	4	0.30	<0.10	<0.14	Nov 66	50	<10
Alaska:	Adak	31		<0.10	<0.10	<0.10	June 66	[c]	
	Anchorage	18	6	0.26	<0.10	<0.14	Mar 66	16	<3
	Attu Island	22		<0.10	<0.10	<0.10	July 66	[c]	
	Fairbanks	16	2	<0.10	<0.10	<0.10	Apr 66	9	<2
	Juneau	19	8	0.12	<0.10	<0.10	July 65	86	<17
	Kodiak	16		<0.10	<0.10	<0.10	May 66	[c]	
	Nome	7		0.12	<0.10	<0.10	Sept 66	[c]	
	Pt. Barrow	27		<0.10	<0.10	<0.10	Aug 66	[c]	
	St. Paul Island	30		<0.10	<0.10	<0.10	Oct 66	[c]	
Aris:	Phoenix	27		0.35	<0.10	<0.17	July 65	[c]	
Ark:	Little Rock	20	4	0.22	<0.10	<0.12	Mar 66	98	<20
Calif:	Berkeley	30		<0.10	<0.10	<0.10	May 66	[c]	
	Los Angeles	20		0.20	<0.10	<0.12	Sept 66	[c]	
C.Z:	Ancón	16		<0.10	<0.10	<0.10	May 66	[c]	
Colo:	Denver	30	6	0.32	<0.10	<0.14	May 66	18	<4
Conn:	Hartford	31	6	0.25	<0.10	<0.15	Apr 66	56	<11
Del:	Dover	20		0.23	<0.10	<0.17	Nov 66	[c]	
D.C:	Washington	23	4	0.28	<0.10	<0.16	Aug 66	12	<2
Fla:	Jacksonville	30	10	0.18	<0.10	<0.11	Mar 66	148	<30
	Miami	30	11	0.24	<0.10	<0.12	Apr 66	176	<35
Ga:	Atlanta	[b]	7				Oct 66	100	<20
Guam:	Agana	28		0.13	<0.10	<0.10	Feb 66	[c]	
Hawaii:	Honolulu	31	1	0.13	<0.10	<0.10	July 66	10	<2
Idaho:	Boise	29		0.29	<0.10	0.17	July 66	[c]	
Ill:	Springfield	30	2	0.29	<0.10	<0.16	Aug 66	18	<4
Ind:	Indianapolis	31	8	0.30	<0.10	<0.18	Oct 66	56	<11
Iowa:	Iowa City	30	4	0.35	<0.10	<0.17	May 66	104	<21
Kans:	Topeka	31	3	0.32	<0.10	<0.14	Mar 66	19	<4
Ky:	Frankfort	27	5	0.33	<0.10	<0.17	Aug 66	29	<6
La:	New Orleans	31	13	0.26	<0.10	<0.13	Aug 66	243	<49
Maine:	Augusta	31	9	0.27	<0.10	<0.16	Sept 66	47	<9
	Presque Isle	24	6	0.20	<0.10	<0.13	May 66	62	<13
Md:	Baltimore	19	2	0.30	<0.10	<0.19	Apr 66	16	<3
	Rockville	17		0.23	<0.10	0.17	July 66	[c]	
Mass:	Lawrence	31	7	0.33	<0.10	<0.20	Nov 66	79	<16
	Winchester	28	8	0.23	<0.10	<0.14	June 66	65	<13
Mich:	Lansing	31	6	0.26	<0.10	<0.15	July 66	37	<7
Minn:	Minneapolis	19	4	0.20	<0.10	<0.14	Feb 66	73	<15
Miss:	Jackson	30	4	0.37	<0.10	<0.13	Sept 66	63	<13
Mo:	Jefferson City	31	6	0.29	<0.10	<0.14	Oct 66	59	<12
Mont:	Helena	31	2	0.29	<0.10	0.20	June 66	8	<2
Nebr:	Lincoln	20	2	1.74	<0.10	<0.21	Oct 66	20	<4
Nev:	Las Vegas	25		0.33	<0.10	<0.18	Apr 66	[c]	
N.H:	Concord	20		0.26	<0.10	0.20	Aug 66	[c]	
N.J:	Trenton	30	2	0.26	<0.10	<0.17	Sept 66	6	<1
N.M:	Santa Fe	29	7	0.25	<0.10	<0.13	June 66	36	<7
N.Y:	Albany	19	4	0.43	<0.10	<0.17	Oct 66	57	<12
	Buffalo	30		0.23	<0.10	<0.15	May 66	[c]	
	New York	30		0.30	<0.10	<0.14	June 66	[c]	
N.C:	Gastonia	31	6	0.27	<0.10	<0.16	May 66	43	<9
N. Dak:	Bismarck	29	6	0.36	<0.10	<0.16	Aug 66	54	<11
Ohio:	Cincinnati	20		0.18	<0.10	<0.11	Nov 66	[c]	
	Columbus	31	9	0.51	<0.10	0.29	Sept 66	119	<24
	Painesville	31	3	0.30	<0.10	0.18	Apr 66	16	<3
Okla:	Oklahoma City	29	2	0.26	<0.10	<0.12	July 66	4	<1
	Ponca City	25	6	0.17	<0.10	<0.11	Apr 66	81	<16
Ore:	Portland	31	6	0.19	<0.10	<0.12	Oct 66	21	<4
Pa:	Harrisburg	31	2	0.24	<0.10	<0.12	Oct 66	8	<2
P.R:	San Juan	26	5	0.42	<0.10	<0.15	Sept 66	109	<22
R.I:	Providence	28	8	0.25	<0.10	<0.14	July 66	70	<14
S.C:	Columbia	27	6	0.27	<0.10	<0.13	June 66	101	<20
S. Dak:	Pierre	31	3	0.36	<0.10	<0.16	July 65	66	<13
Tenn:	Nashville	31	5	0.25	<0.10	<0.13	July 66	81	<16
Tex:	Austin	31	2	0.66	<0.10	<0.16	Nov 66	7	<1
	El Paso	31	4	0.27	<0.10	<0.13	Aug 66	15	<3
Utah:	Salt Lake City	31	5	0.34	<0.10	<0.17	Sept 66	7	<2
Vt:	Barre	29	8	0.27	<0.10	<0.16	Mar 66	56	<11
Va:	Richmond	31	6	0.23	<0.10	<0.14	Mar 66	129	<26
Wash:	Seattle	29	6	<0.10	<0.10	<0.10	Mar 66	29	<6
	Spokane	31		0.30	<0.10	<0.15	Feb 66	[c]	
W. Va:	Charleston	28	9	0.26	<0.10	<0.15	June 66	105	<21
Wis:	Madison	29	6	0.21	<0.10	<0.13	Mar 66	107	<22
Wyo:	Cheyenne	30	5	0.29	<0.10	<0.14	Apr 66	66	<16
Network summary		1,958	291	1.74	<0.10	<0.14		59	<12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If more than 10 percent of the samples contain <0.10 pCi/m³, a less-than sign is placed before the average.
[b] No report received.
[c] No precipitation sample collected.

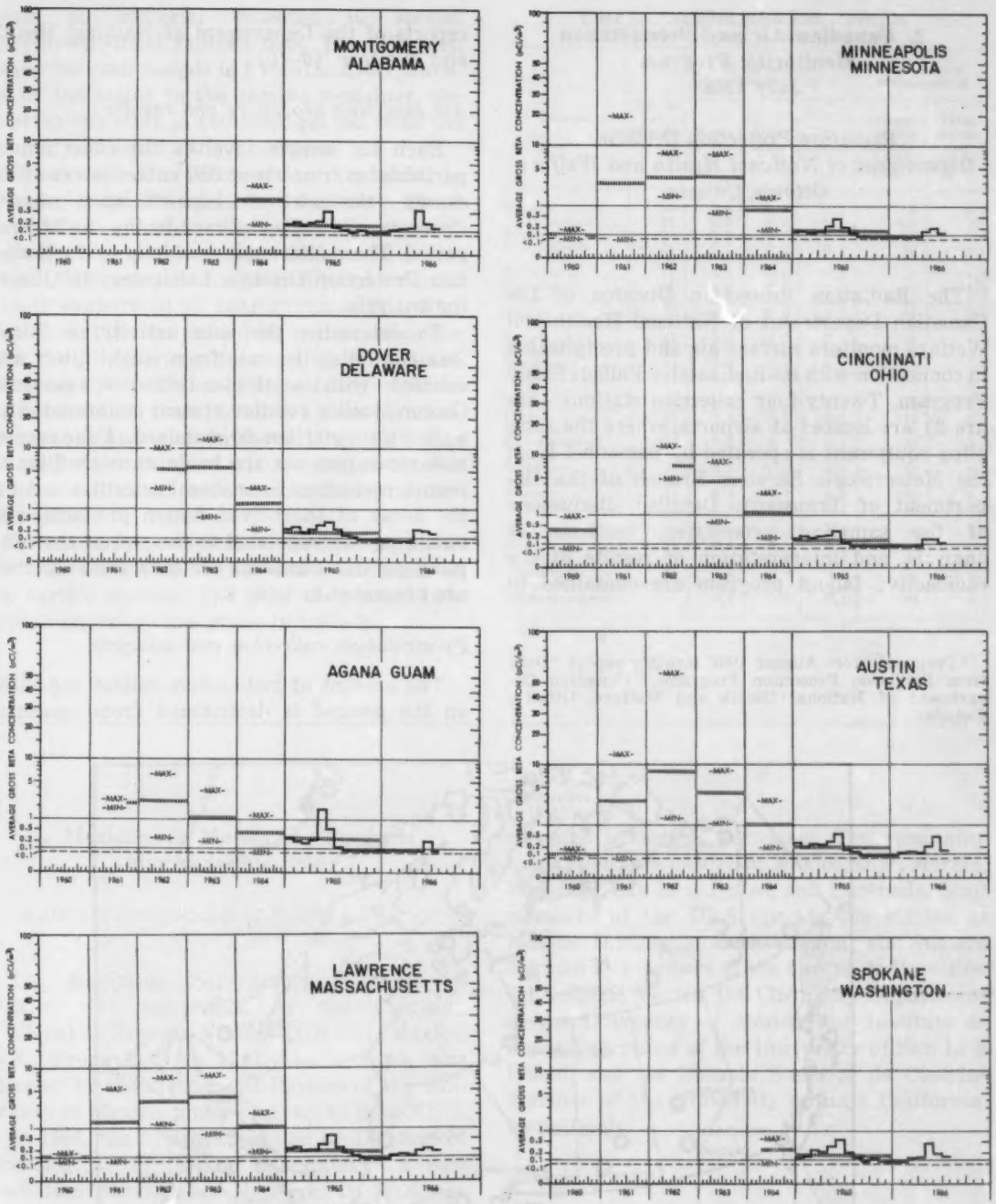

Figure 2. Monthly and yearly profiles of beta activity in air—Radiation Surveillance Network, 1960–July 1966

2. Canadian Air and Precipitation Monitoring Program July 1966[2]

Radiation Protection Division
Department of National Health and Welfare
Ottawa, Canada

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations (figure 3) are located at airports, where the sampling equipment is operated by personnel from the Meteorologic Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*6–10*).

Air sampling procedure and results

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch diameter glass-fiber filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa for analysis.

To determine the beta activity, a 2-inch diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system calibrated with a strontium-yttrium–90 standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for July 1966 are presented in table 2.

Precipitation collection and analysis

The amount of radioactive fallout deposited on the ground is determined from measure-

[2] Prepared from August 1966 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

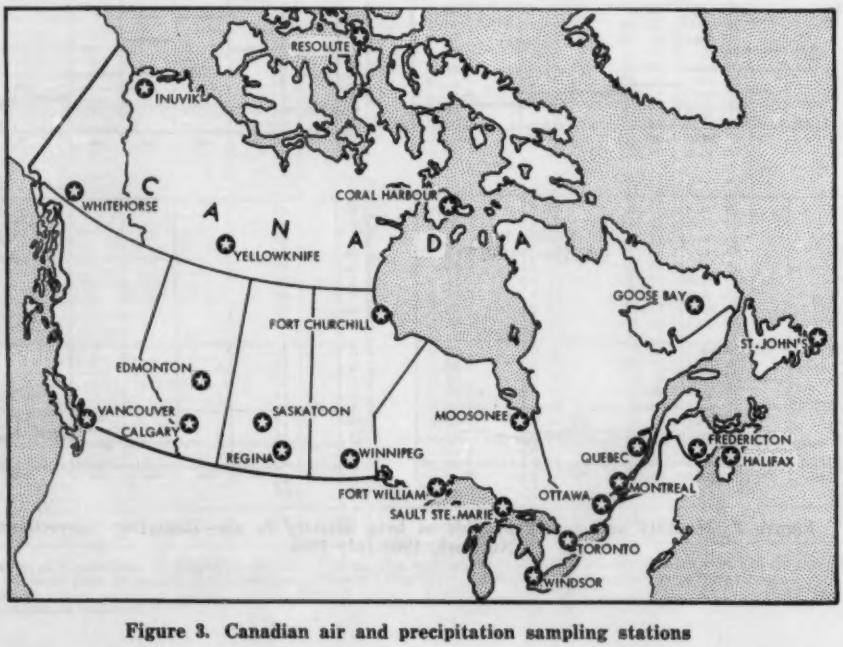

Figure 3. Canadian air and precipitation sampling stations

ments on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is 1 month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are added to selected samples depending upon the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter together with the polyethylene liner is then ignited and ashed at 450°C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infrared lamp, and then counted with a thin-end window Geiger-Mueller counter calibrated with a strontium-yttrium–90 source.

The monthly precipitation samples represent the total deposition of radioactive materials on the earth's surface. The July 1966 gross beta deposition values are given in table 2.

Table 2. Canadian gross beta activity in surface air and precipitation, July 1966

Station	Number of samples	Air surveillance activity, pCi/m³			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.4	0.0	0.2	54	6.1
Coral Harbour	31	0.3	0.0	0.1	NS	NS
Edmonton	31	0.3	0.0	0.1	77	7.7
Ft. Churchill	31	0.2	0.0	0.1	95	0.7
Ft. William	31	0.2	0.0	0.1	23	1.0
Fredericton	31	0.2	0.0	0.1	59	4.3
Goose Bay	13	0.2	0.0	0.1	13	2.7
Halifax	31	0.2	0.0	0.1	64	2.9
Inuvik	31	0.3	0.0	0.1	46	1.2
Montreal	14	0.3	0.1	0.2	59	4.2
Moosonee	31	0.3	0.1	0.2	NS	NS
Ottawa	31	0.3	0.0	0.2	52	4.1
Quebec	30	0.2	0.1	0.1	48	3.3
Regina	31	0.4	0.0	0.2	119	3.4
Resolute	31	0.1	0.0	0.0	94	1.4
St. John's, Nfld.	30	0.2	0.0	0.1	24	2.0
Saskatoon	30	0.3	0.0	0.2	95	4.6
Sault Ste. Marie	29	0.3	0.0	0.2	97	3.2
Toronto	31	0.4	0.1	0.2	109	1.9
Vancouver	31	0.2	0.0	0.1	45	2.9
Whitehorse	31	0.2	0.0	0.1	79	2.5
Windsor	31	0.4	0.1	0.2	34	3.4
Winnipeg	31	0.4	0.0	0.2	40	3.4
Yellowknife	31	0.2	0.0	0.1	79	1.2
Network summary	—	0.4	0.0	0.1	64	3.1

NS, no sample.

3. Mexican Air Monitoring Program May and June 1966

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energia Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F., Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de Mexico, the Chemistry Department of the University of Mérida, the Institute de Zonas Déserticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day, using high-volume samplers.

Figure 4. Fallout network sampling stations in Mexico

After each 20-hour sampling period, the filter is removed and shipped via air mail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta activity, allowing a minimum of 3 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a mimimum of eight samples per month were needed to get a reliable average activity at each station (*11*).

The maximum, minimum, and average fission product beta concentrations in surface air during May and June 1966 are presented in tables 3 and 4.

Table 3. Mexican gross beta activity of airborne particulates, May 1966

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	11	3.7	<0.1	1.0
Ciudad Juarez	15	2.6	0.1	0.5
Ensenada	3	0.3	0.2	0.2
Guadalajara	10	0.6	0.1	0.2
Guaymas	9	0.5	<0.1	0.3
La Paz	4	0.2	0.1	0.1
Matamoros	NS			
Mazatlán	NS			
Mérida	9	1.5	0.1	0.8
México, D.F.	6	0.2	0.1	0.1
Nuevo Laredo	9	0.6	0.1	0.2
San Luis Potosí	14	3.6	<0.1	0.6
Tampico	8	1.2	<0.1	0.4
Torreón	15	2.2	0.1	0.5
Veracruz	8	1.1	0.1	0.5

NS, no sample collected: station temporarily shut down.

Table 4. Mexican gross beta activity of airborne particulates, June 1966

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	8	7.3	0.3	3.0
Ciudad Juarez	15	1.1	0.2	0.6
Ensenada	NS			
Guadalajara	NS			
Guaymas	5	1.3	0.3	0.6
La Paz	11	0.8	0.2	0.4
Matamoros	NS			
Mazatlán	15	3.2	0.3	0.9
Mérida	12	0.9	0.1	0.5
México, D.F.	9	1.3	0.1	0.5
Nuevo Laredo	9	1.6	0.2	0.6
San Luis Potosí	NS			
Tampico	12	1.9	0.3	0.8
Torreón	15	3.8	0.1	0.7
Veracruz	16	1.0	0.1	0.4

NS, no sample collected: station temporarily shut down.

4. Pan American Air Sampling Program July 1966

Pan American Health Organization and *U.S. Public Health Service*

Gross beta activity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO), and the U.S. Public Health Service (PHS) to assist PAHO member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station locations are shown in figure 5.

Table 5. PAHO gross beta activity in surface air, July 1966

Station location	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	10	6.71	<0.10	<0.38
Chile: Santiago	30	46.56	<0.10	<3.74
Colombia: Bogota	18	<0.10	<0.10	<0.10
Ecuador: Guayaquil	30	13.72	<0.10	<1.69
Jamaica: Kingston	25	0.17	<0.10	<0.11
Peru: Lima	20	72.04	<0.10	<9.44
Venezuela: Caracas	15	<0.10	<0.10	<0.10
West Indies: Trinidad	19	<0.10	<0.10	<0.10
Pan American summary	176	72.04	<0.10	<1.95

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If 10 percent or more of the samples from a station contain <0.10 pCi/m³, a less-than sign is placed before the average.

The July 1966 air monitoring results from the participating countries are given in table 5. Fresh fission products, presumably from the

Figure 5. Pan American Air Sampling Program stations

French test on July 2, 1966, were identified as shown in table 6.

Table 6. Occurrence of fresh fission products in PAHO samples

Station	Inclusive date	Peak gross beta activity, pCi/m³ (at time of collection)
Lima, Peru	July 12–20, 1966	72.04
Santiago, Chile	July 7–11, 1966	46.56
Buenos Aires, Argentina	July 9–13, 1966	6.71
Guayaquil, Ecuador	July 14–22, 1966	13.72

The activities observed on these PAHO air samples were comparable to those observed at the various U.S. stations during Chinese testing.

A slight increase in activity was also noted during the last week of July 1966 at Santiago, Chile. Gamma analysis of the July 30, 1966, Santiago sample and a sample from Lima, Peru, for August 1, 1966, showed small quantities of fresh fission products.

5. Plutonium in Airborne Particulates April–June 1966

Division of Radiological Health
Public Health Service

The Radiation Surveillance Network (RSN) of the Division of Radiological Health, Public Health Service, located at Rockville, Maryland, is continuing routine analysis for plutonium in air particulates. These analyses were initiated during 1965 as part of the mission to establish, maintain, and operate a national surveillance network to measure radioactivity in the environment.

Air filters from eleven RSN stations are analyzed monthly for plutonium. Each daily filter is counted for gross beta activity and for gamma emitters by gamma spectrometry 4 to 5 days after collection. For plutonium analysis, a monthly composite is made of one-half of each individual sample for each station. Each composite representing 10,000 to 20,000 cubic meters of air is analyzed by gamma spectrometry prior to the plutonium analysis.

Data for the months of November 1965 through March 1966, with details of the method of collection and radiochemical analysis, were presented in an earlier report (*12*). Results for April to June 1966 are given in table 7.

Table 7. Plutonium in airborne particulates April–June 1966

Station location	Plutonium content, pCi/1,000 m³ [a]		
	April	May	June
Alaska: Anchorage	0.194	0.079	0.096
Ariz: Phoenix	0.369	0.239	0.215
Colo: Denver	0.198	0.239	0.191
Hawaii: Honolulu	0.154	0.117	0.087
La: New Orleans	0.149	0.110	0.169
Md: Rockville	0.111	0.174	0.202
N.C: Gastonia	0.159	0.159	0.208
N.Y: Buffalo	0.092	0.146	0.119
S. Dak: Pierre	0.149	0.197	0.132
Tex: Austin	0.144	0.134	0.151
Wash: Seattle	0.095	0.094	0.051

[a] Plutonium includes plutonium-238, plutonium-239, and plutonium-240.

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(*12*) RUSSELL, J., H. LEVINE, and R. SCHNEIDER. Plutonium in airborne particulates, November 1965 through March 1966. Radiol Health Data Rep 7:483–484 (August 1966).

Section IV. Other Data

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, and environmental monitoring reports.

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by the AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of environmental radioactivity data follow for the Lawrence Radiation Laboratory and the Mound Laboratory.

[1] Part 20, "Standards for Protection Against Radiaton," AEC Rules and Regulations, contains essentially the standards published in the "AEC Manual." The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

1. Lawrence Radiation Laboratory July–December 1965[2]

University of California
Berkeley, California

Berkeley Site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is located to the east of the University of California campus (figure 1). Winds are generally westerly; annual rainfall is 23 inches, most of which usually falls during the period from November through April. Technical facilities include a 6.3 BeV proton accelerator (Bevatron), a 700–MeV cyclotron, a 10–MeV linear accelerator, an 88-inch cyclotron, and various chemistry and physics laboratories.

The environmental sampling program includes monitoring of the atmosphere, surface

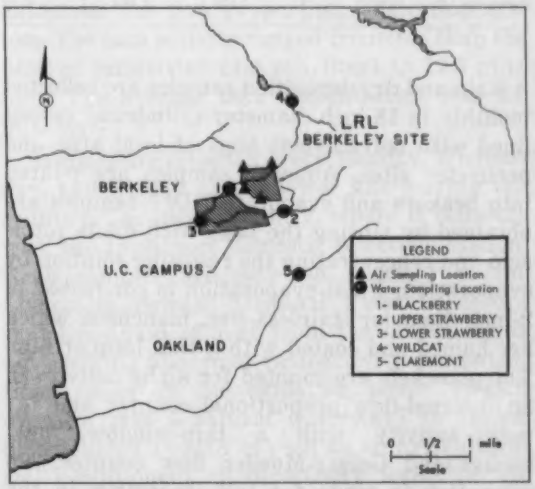

Figure 1. Environmental sampling locations at the Berkeley site

[2] Summarized from "Results of Environmental Radioactivity Sampling Program," Lawrence Radiation Laboratory, second half 1965.

and ground waters, sewage, rain, and dry depositions. Three types of atmospheric samples are taken: stack samples, local area samples, and perimeter samples.

Approximately 110 "stacks" with potential for releasing radioactive contaminants are sampled continuously at a flow rate of 1 liter per minute. The 1-inch-diameter filters are changed weekly and counted for beta activity by an end-window Geiger-Mueller tube, and for alpha activity by a thin-window proportional counter. Local area and perimeter air samples are taken at locations on the laboratory site and at the property line, respectively. The samples are obtained on 4- by 9-inch HV–70 filter papers at 4 cubic feet per minute. The filters are changed weekly and counted for alpha activity by a thin-window proportional counter, and for beta activity by a 30-mg/cm^2 end-window Geiger-Mueller tube. A 40 percent loss in the alpha count is assumed for self absorption. The average levels of activity observed in each type of sample are given in table 1.

Table 1. Atmospheric monitoring, Berkeley site July–December 1965

Sampling locations (number of locations)	Number of samples	Average concentrations (pCi/m^3)	
		Alpha activity	Beta activity
Stacks (111)	4,612	0.008	2.0
Local area (10)	253	0.001	0.11
Perimeter (4)	102	0.001	0.12

Rain and dry deposition samples are collected monthly in 18-inch-diameter cylindrical vessels lined with polyethylene bags at local area and perimeter sites. Aqueous samples are poured into beakers and evaporated. Dry samples are obtained by rinsing the bags with dilute nitric acid and concentrating the resulting solution by evaporation. Final evaporation is conducted in 2-inch-diameter stainless-steel planchets, which are flamed and coated with a thin lacquer film. The planchets are counted for alpha activity in an internal-flow proportional counter and for beta activity with a thin-window, low-background Geiger-Mueller flow counter. No correction is made for self-absorption in the sample. Deposition data are given in table 2.

Table 2. Total deposition, Berkeley site July–December 1965

Sampling locations (number of locations)	Number of samples	Average concentrations (nCi/m^2)	
		Alpha activity	Beta activity
Local area (10)	58	0.15	2.86
Perimeter (4)	24	0.12	4.56

Water samples are taken from sewers, onsite streams, and offside streams. Two sewer lines serve the LRL area. The "Hearst" sewer receives waste from the larger part of the area. A sampling system takes a continuous proportional sample from the Hearst sewer as it leaves the laboratory boundary. Samples are also taken of waste feeding into the Hearst sewer from buildings 70, 70A, and 71. The "Strawberry" sewer receives waste from the southeast part of the laboratory site. A monitoring station takes a continuous proportional sample from this sewer. Continuous samples are also taken from the acid waste systems in building 74 which is the most likely contributor of radioactivity to this sewer line. The concentrations of radioactive wastes in sewage, shown in table 3, are either those observed directly in samples from the sewer line or those calculated from samples taken from contributing waste streams, whichever has the higher value. Strawberry and Blackberry Creeks comprise the laboratory's storm drainage. These are sampled weekly at three locations. Two other nearby offsite streams are also sampled weekly. All water samples are handled in the same manner as rain samples. The results from the water sampling program are presented in table 3.

Table 3. Water monitoring, Berkeley site July–December 1965

Type and source of sample	Number of samples	Average concentrations (pCi/liter)	
		Alpha activity	Beta activity
Sewage:			
Hearst sewer	34	0.42	34.7
Strawberry sewer	25	0.05	26.0
Tap water	24	0.03	3.0
Surface water:			
Onsite streams	77	0.80	7.8
Offsite streams	52	0.54	3.5

Livermore site

The Livermore site of LRL (figure 2) is located about 50 miles southeast of San Francisco, California. Annual precipitation in the Livermore Valley is about 14 inches; prevailing winds are from the west with frequent nocturnal inversions. Technical facilities include a small cyclotron, a 2-megawatt swimming pool reactor, and physics and chemistry programs associated with a weapons development program.

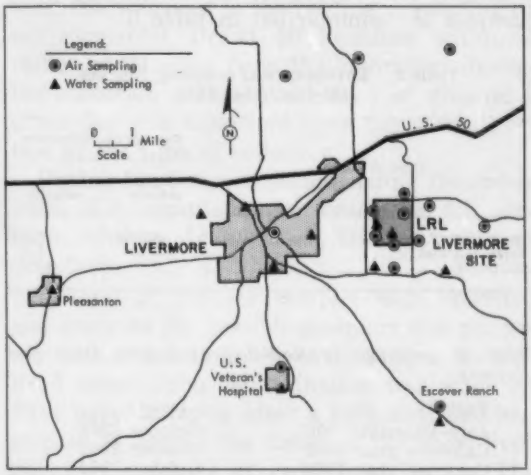

Figure 2. Environmental sampling locations at the Livermore site

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, and sewage plant products. Air samples are collected to ascertain that control efforts are restricting the release of radioactivity from the laboratory to levels which do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water samples are collected to monitor radioactivity in an underground water supply which provides most of the domestic water for the cities of Livermore and Pleasanton, and is the sole supply for ranches in the Livermore and Amador Valleys.

Air samples are collected continuously at 15 sites within 5 miles of the laboratory. Samples are collected at a rate of 4 cfm on 100-square centimeter HV–70 filter papers, which are changed after every 7 days of operation. A minimum decay period of 96 hours is observed before the samples are counted to eliminate the effect of natural radon and thoron daughters.

All environmental air samples are counted in an automated system which utilizes gas flow proportional detectors for both alpha and beta activities measurements. Alpha activity in 375 air samples averaged 0.0009 pCi/m^3, while beta activity averaged 0.072 pCi/m^3.

The measurement of low-level "background" radiation during the 6-month period was accomplished with fluoroglass dosimeters located at nine points on the site perimeter and at two nearby ranches. The dosimeters, which have a detection limit of 50 mR, were read after 6 months of exposure. Only one dosimeter, opposite one irradiation facility, indicated detectable external radiation amounting to an average dose rate of 0.02 mR/hr for the 6-month period. The average dose rate at the laboratory perimeter, based upon this one detectable dose, was determined to be less than 0.01 mR/hr.

Domestic water samples are collected monthly from nine nearby areas. No water sample showed an alpha concentration above the limit of sensitivity (5.0 pCi/liter) for the automatic gas flow proportional detection system. The beta activity ranged from less than the limit of sensitivity (1.8 pCi/liter) to 12.3 pCi/liter. The average beta concentration was 2.8 pCi/liter.

Samples are collected every Monday, Wednesday, and Friday at the sewer line leaving the southwest project boundary, where it connects with the Livermore domestic sewerage system. Grab samples are collected monthly at the Livermore Sewage Disposal Plant to assure that the liquid effluent from the laboratory is not creating abnormal radioactivity concentrations either in the oxidation ponds (which overflow into a natural waterway) or in the dried sludge (which is used as an agricultural soil conditioner). Radioactivity levels in the raw sewage, oxidation ponds, and dried sludge are summarized in table 4.

Table 4. Environmental sampling, Livermore July–December 1965

Type of sample	Average concentration	
	Alpha activity	Beta activity
Raw sewage, pCi/liter	5.4	61
Oxidation ponds, pCi/liter	12	70
Dried sludge, pCi/g	60	18

Samples of top layer soil are collected quarterly at the 19 sampling stations surrounding the Livermore site. The alpha activity fluctuated from less than the limit of sensitivity (1.5 pCi/g) to 12 pCi/g. The beta activity fluctuated from less than the limit of sensitivity (3.5 pCi/g) to 25 pCi/g. The average alpha concentration was 2.0 pCi/g and the average beta concentration was 9.9 pCi/g. The concentrations are in the normal range for soil in the Livermore Valley.

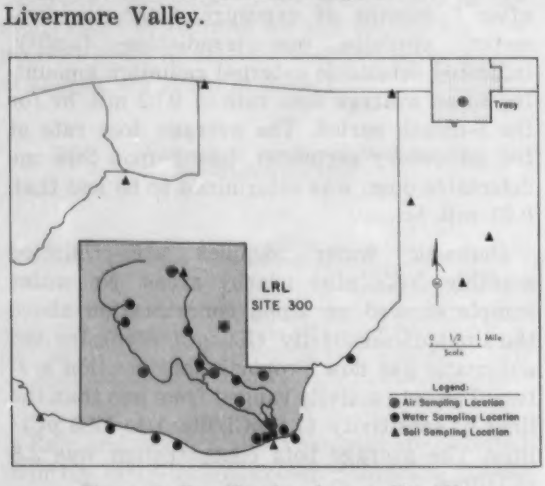

Figure 3. Sampling locations at Site 300 Lawrence Radiation Laboratory

Site 300

Site 300 (figure 3) is located in a very sparsely populated ranching area about 17 miles southeast of the Lawrence Radiation Laboratory at Livermore. Air and water samples are taken to determine whether operations at Site 300 are changing the normal radioactivity in levels in the vicinity. The eight air samplers at Site 300 are operated at about 50 cfm on a continuous basis with the filter papers being changed on an irregular schedule. Most of these air samplers are located within the boundaries of the test site due to unavailability of power facilities offsite. Water samples are taken from six onsite wells because they are the only readily accessible sources of underground water. Samples are collected from streams only during the winter months when water flow exists. Soil samples are collected monthly at nine offsite locations. Only top layer soil is collected to determine fallout concentrations. All air, water, and soil samples are processed at the laboratory in Livermore. The average radioactivity levels in all types of samples are summarized in table 5.

Table 5. Environmental sampling, Site 300 July–December 1965

Type of sample	Average concentration	
	Alpha activity	Beta activity
Air, pCi/m³	0.0004	0.069
Water, pCi/liter	<5.0	5.3
Soil, pCi/g	4	15

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1961	October 1962
Calendar year 1962	October 1963
Calendar year 1963	October 1964
January–June 1964	May 1965
July–December 1964	November 1965
January–June 1965	May 1966

2. Mound Laboratory July–December 1965[3]

Monsanto Research Corporation
Miamisburg, Ohio

During the period covered by this report, radioactive materials from Mound Laboratory did not contribute any measurable penetrating radiation, such as gamma or hard beta, to the environment. Of the radionuclides in use at Mound Laboratory, only polonium–210, plutonium–239, and hydrogen–3 (tritium) are potential environmental contaminants.

[3] Summarized from "Environmental Monitoring Report: July–December 1965 and 1965 Summary" (MLM–1335).

The environmental monitoring program, conducted by the Monsanto Research Corporation, is planned and coordinated with regard to all of the various projects performed in the laboratory. Air and water monitoring methods and results are discussed below.

Air monitoring

Mobile air monitoring equipment, mounted on a 1-ton panel truck, for measurement of tritium and collection of particulate alpha emitters, was used in the routine monitoring of environmental air at 96 locations within a radius of 20 miles from the laboratory during the collection period. The choice of sites on a given day was dependent upon the wind direction at the time of collection.

During the 6-month period ending December 1965, 328 samples were evaluated for airborne tritium. In all cases, tritium was nondetectable.

A total of 309 air samples were collected and analyzed for possible polonium and plutonium contaminants in the environment. A long-lived gross alpha determination was made on filter paper samples after a sufficient time had elapsed to permit the decay of the short-lived daughter products of radon and thoron. The filter paper samples were counted for alpha particle emissions in a low background proportional counter. The average measured concentrations of alpha activity in air are summarized in table 6. No specific determinations of polonium–210 or plutonium–239 were made, since the gross alpha activity remained substantially below the environmental limits for these nuclides.

Table 6. Atmospheric monitoring of long-lived alpha concentrations, Mound Laboratory environs, July–December 1965

Sampling locations (number of sites)	Number of samples	Average concentration (pCi/m^3)
Upwind from laboratory (16)	52	0.0014
Downwind from laboratory (95)	309	0.0025

Water monitoring

Liquid radioactive waste materials from polonium and plutonium operations at the laboratory are processed in special waste disposal plants designed to reduce radioactivity to a concentration at which it may be discharged to the Great Miami River.

Helium–3, which is purified at the Mound Laboratory, contains small quantities of tritium. Liquid wastes from this operation are treated separately to assure that the radioactivity level is below the maximum permissible concentration before discharge to the Great Miami River.

Weekly water samples are collected from a drainage ditch and five locations along the Great Miami River as shown in figure 4. Additional samples are taken quarterly at more distant downstream points. The drainage ditch carries all storm sewer water and liquid tritium and treated plutonium wastes from the plant site. Sampling location number 2 (figure 4) is located at the point of discharge of the laboratory polonium waste disposal plant effluent to the Great Miami River, and number 6 at Franklin, Ohio, is 5 miles downstream from the effluent outlet.

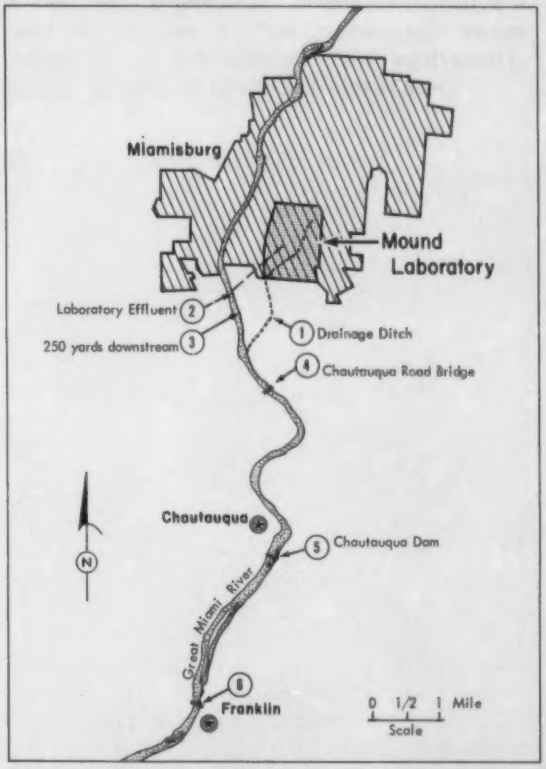

Figure 4. Water sampling locations, Mound Laboratory

All of the river samples are analyzed for polonium–210. The drainage ditch samples and some of the river samples are analyzed for hydrogen–3 (tritium). The drainage ditch samples are also analyzed for plutonium–239. Average concentrations of hydrogen–3 (tritium), polonium–210, and plutonium–239 are given in table 7 for the final 6 months of 1965.

Previous coverage in *Radiological Health Data and Rports*:

Period	Issue
January–June 1962	March 1963
July 1962–June 1963	April 1964
July–December 1963	November 1964
January–June 1964	May 1965
July–December 1964	November 1965
January–June 1965	May 1966

Table 7. Offsite water monitoring for radioactivity Mound Laboratory environs, July–December 1965

Nuclide and sampling locations [a]	Number of samples	Average concentration (pCi/liter)
Polonium-210		
2 (laboratory effluent)	24	83.8
3 (250-yards downstream)	24	0.2
4 (Chautauqua Road Bridge)	24	0.4
5 (Chautauqua Dam)	24	0.2
6 (Franklin, Ohio)	24	0.1
Trenton, Ohio	2	0.0
New Miami, Ohio	2	1.4
7 miles upstream from New Baltimore, Ohio	2	0.0
New Baltimore, Ohio	2	0.0
Miamitown, Ohio	2	0.0
Elizabethtown, Ohio	2	0.0
Hydrogen-3 (tritium)		
1 (drainage ditch)	25	320,000
2 (laboratory effluent)	25	430,000
4 (Chautauqua Road Bridge)	24	50,000
Plutonium-239		
1 (drainage ditch)	25	160

[a] See figure 4 for sampling locations.

Section V. Technical Notes

REPORTED NUCLEAR DETONATIONS, OCTOBER 1966

During October 1966, no U.S. nuclear tests were reported. Detection of a Soviet test and of one detonation on the Chinese mainland was announced by the U.S. Atomic Energy Commission. On October 19, 1966, seismic signals originating from the Soviet nuclear test area in the Semipalatinsk region also were recorded. The signals were equivalent to those of a nuclear test in the low-intermediate (20 to 200 kilotons TNT) yield range.

On October 27, 1966, it was announced that the Soviet Union conducted an underground test in their northern testing area of Novaya Zemlya. Seismic signals indicated a yield within the intermediate-to-high yield range (200 kilotons to more than a megaton TNT equivalent).

Also on October 27, 1966, the Atomic Energy Commission detected a nuclear explosion in the general area of the Chinese nuclear test site at Lop Nor. Preliminary estimates indicated a yield in the low to low-intermediate range (under 20 to 200 kilotons TNT equivalent), similar to that of the first Chinese test.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

NUCLEAR POWER PRODUCTION AND ESTIMATED KRYPTON–85 LEVELS. *J. R. Coleman* and *R. Liberace. Radiological Health Data and Reports, Vol. 7, November 1966,* pp. 615–621.

Worldwide environmental levels of krypton–85 are projected to the year 2060, based on published estimates of population increase and prediction of world power needs. Factors considered include estimates of the growth of nuclear reactor power as a fraction of total power production, the "mix" of the reactor economy (thermal, thermal converter, and fast breeder systems), and the decay rate of the krypton–85 inventory. Krypton–85 buildup is discussed in relation to population dose and also to the possible effect of krypton–85 contamination on the uses of noble gases.

KEY WORDS: environmental contamination, fast breeder system, krypton–85, noble gases, nuclear energy, nuclear reactor power, population dose, thermal converter system, thermal system, year 2060.

FILM BADGE SERVICE PERFORMANCE. *D. E. Barber. Radiological Health Data and Reports, Vol. 7, November 1966,* pp. 623–626.

Approximately 2,000 film badges were irradiated with various types and energies of radiation to provide measures of film badge service accuracy upon which provisional performance control limits could be based. Exposures ranged from 2 milliroentgens to 497 roentgens. Film badge services 1) helped design the test procedures, 2) submitted badges for exposure, 3) reported exposure interpretations, and 4) assisted in determining provisional performance control limits. A measure of accuracy called an *error factor* was determined for each service for each type and energy of radiation in the test. These error factors are tabulated to show the accuracy of the film badge services tested. Frequency distributions of the error factors served as the basis for selection of provisional control limits to be used to define acceptable performance.

KEY WORDS: beta exposure, fast neutron, film badges, gamma, National Sanitation Foundation, X-radiation.

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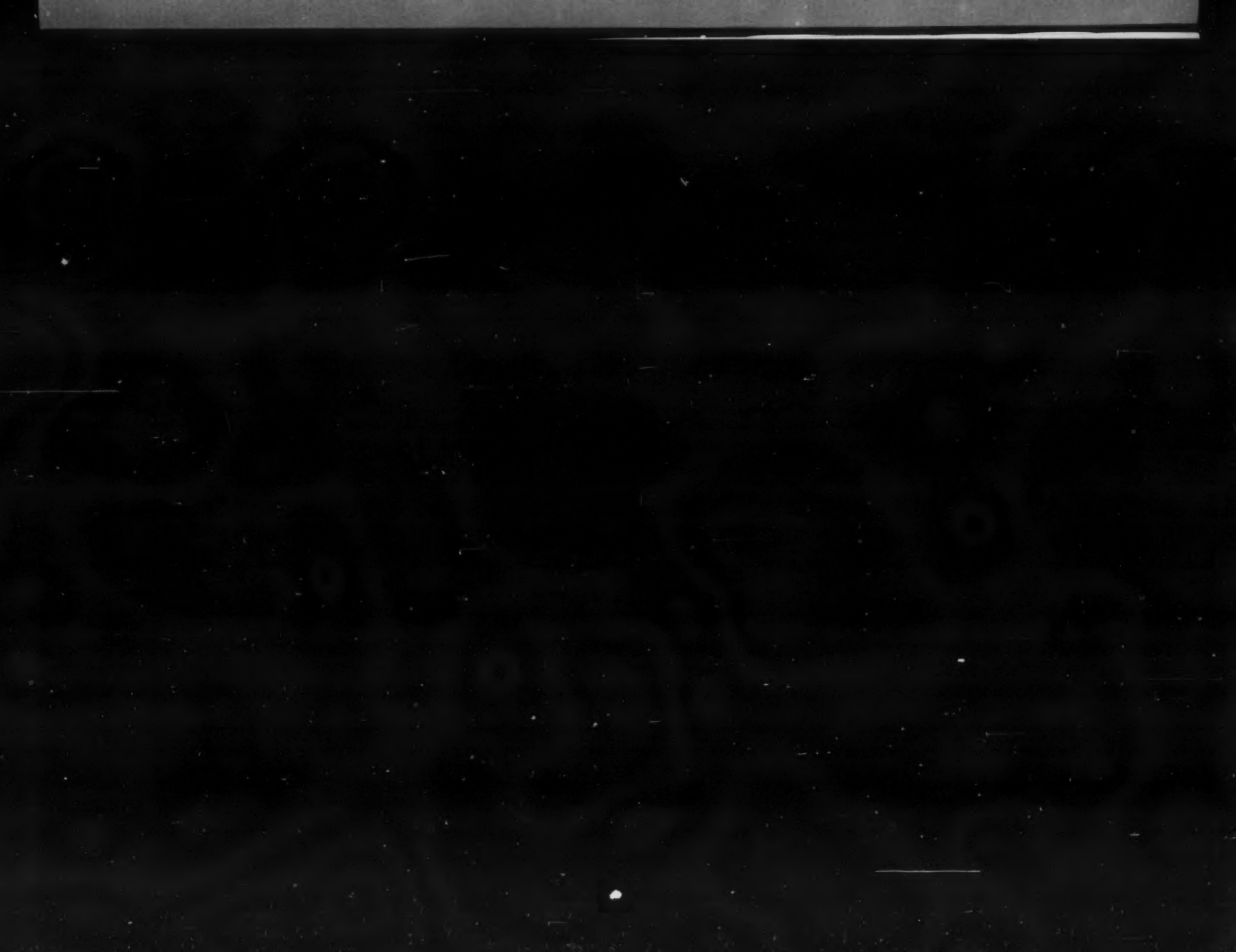

SYMBOLS, UNITS, AND EQUIVALENTS

Symbols	Units	Equivalents
BeV	billion electron volts	equals GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volts	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs per gram

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

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